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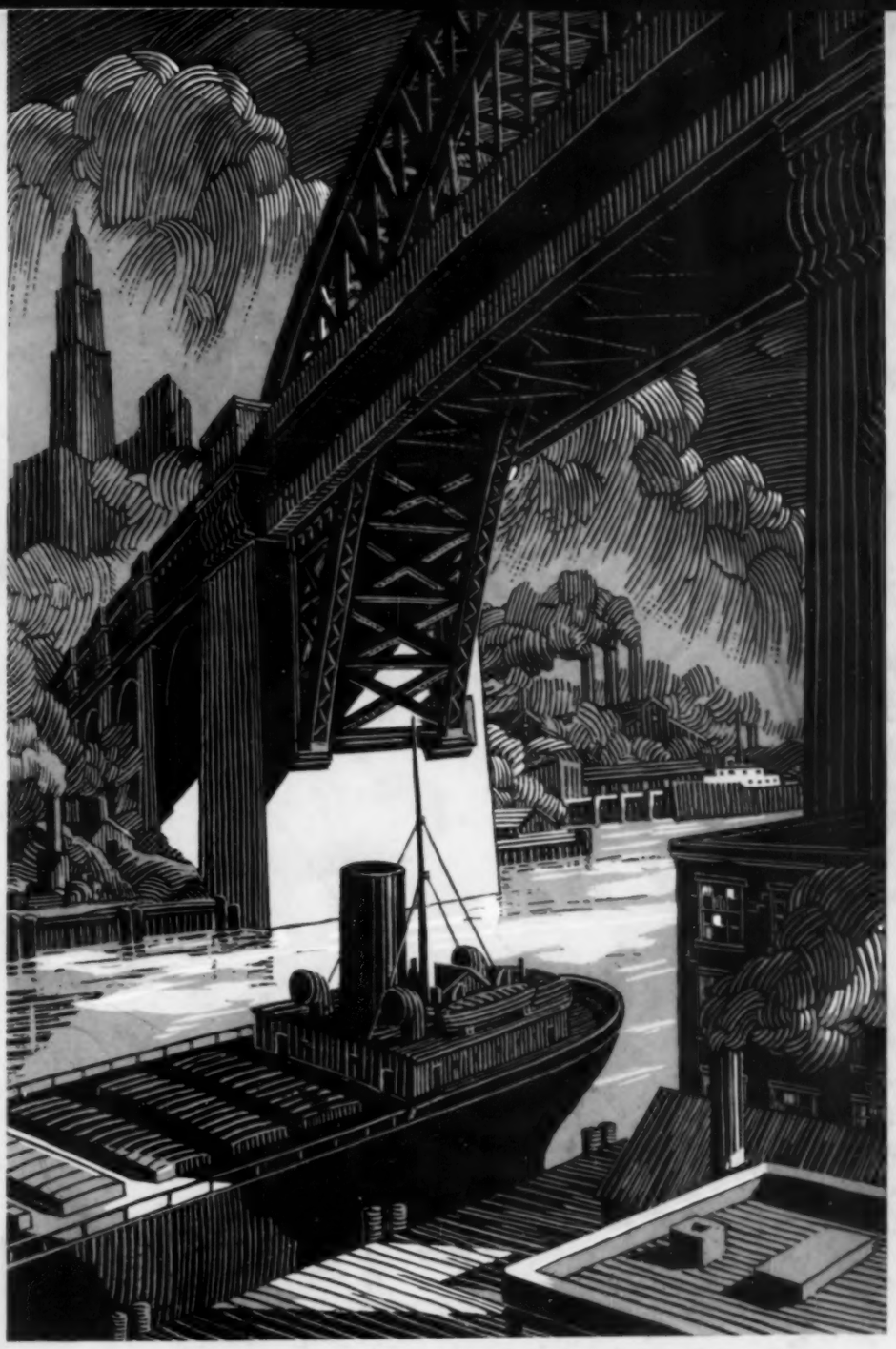

METAL PROGRESS

JUNE 1933

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METAL CONGRESS

June, 1933
Vol. 23, No. 6

METAL PROGRESS

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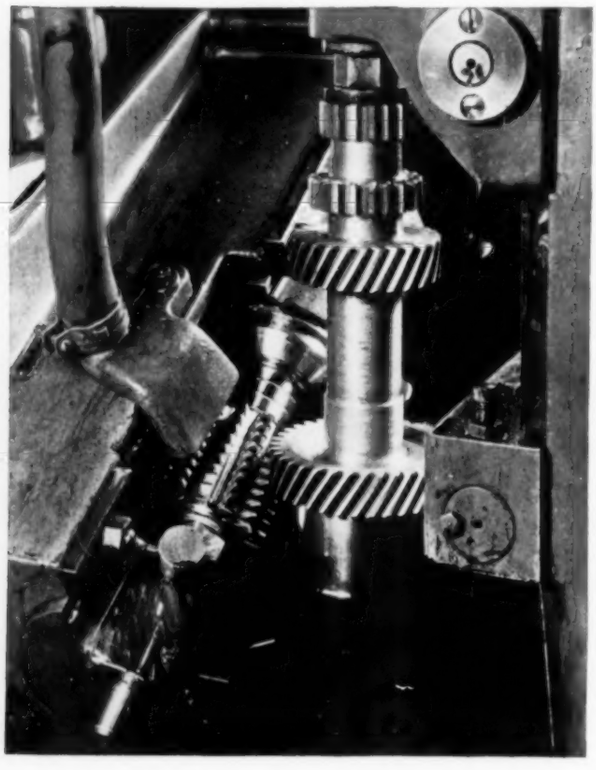

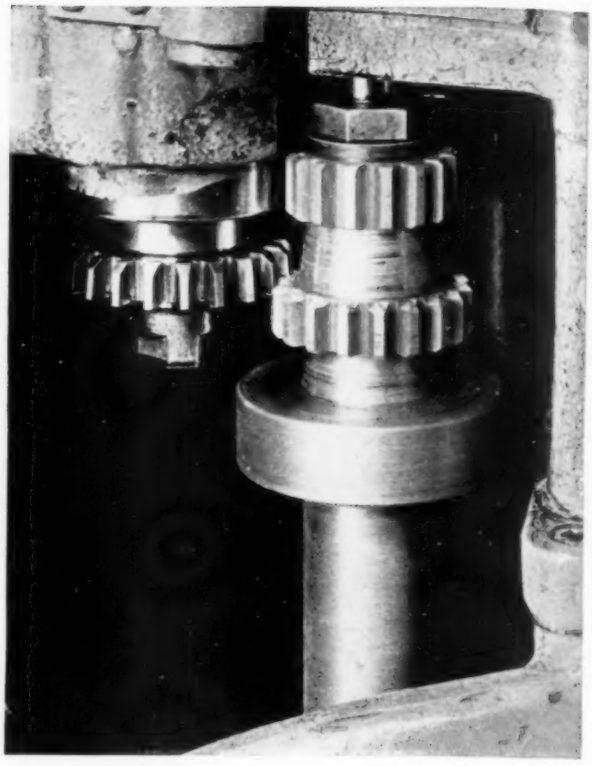

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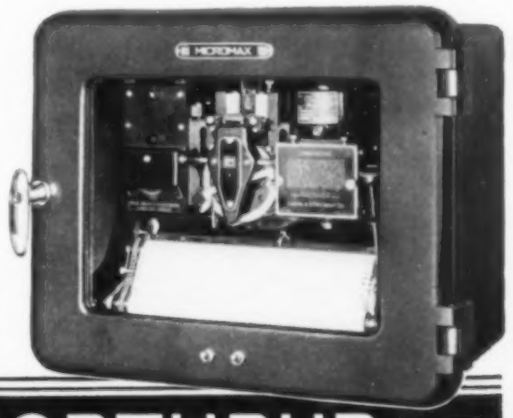

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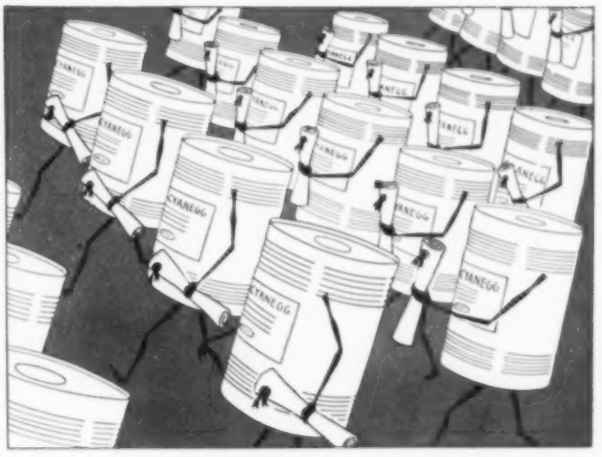

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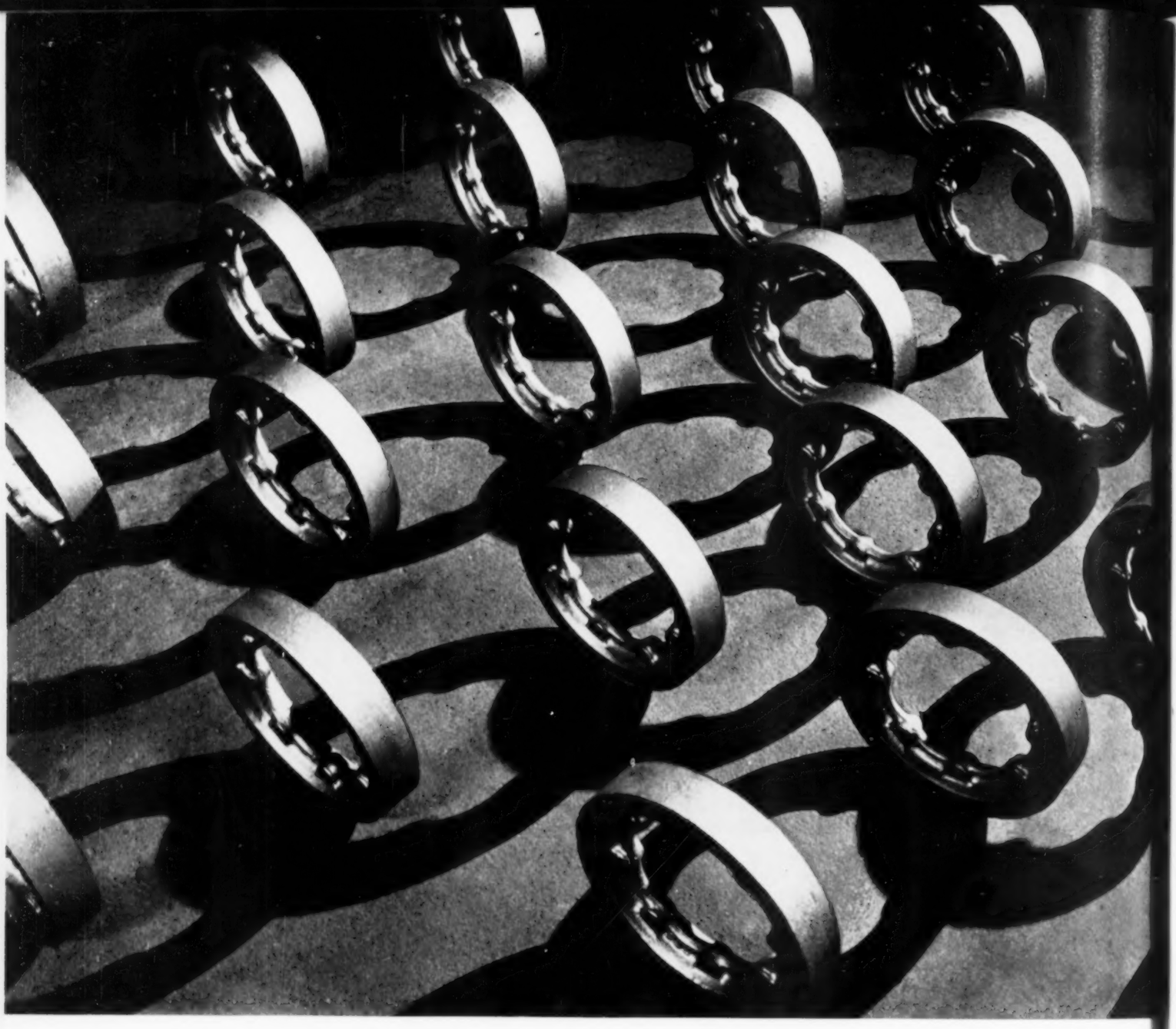


Bronze, For Heavy Duty

By Francis W. Rowe
Chief Metallurgist
David Brown & Sons, Ltd.
Huddersfield, England

CENTRIFUGAL

bronze gear blanks

UTILITY of bronze, and particularly phosphor bronze, for duties necessitating low coefficient of friction and resistance to frictional wear has long been recognized. The superiority of the copper-tin alloys for this work is due to the type of structure they possess and the particular micro-constituents of the alloys.

Up to about 6% tin the cast bronzes consist of crystals of the alpha solid solution of tin in copper (more or less homogeneous in character) and having a hardness, expressed in terms of Brinell, ranging from 60 to 80 dependent on the particular treatment the alloy has received. When the tin content exceeds 6 or 7% a new constituent — the alpha-delta eutectoid — makes its appearance. This constituent is hard, white and brittle; it contains of itself 27% tin and has a hardness, again expressed in terms of Brinell, of approximately 410.

In a copper-tin alloy with 10 to 12% of tin (such as is generally used for hard bearings and gear blanks) approximately one-tenth of the volume consists of these hard crystals of alpha-delta eutectoid embedded in a matrix of the relatively soft alpha solid solution. The aggregate therefore very naturally possesses properties quite unlike other non-ferrous alloys and is analagous to the asphalt-granite mixture used for roads. In a cast bronze the eutectoid particles represent the granite chips which give the necessary hardness and resistance to wear whilst the solid solution corresponds to the asphaltic matrix giving the plasticity and resilience and preventing the mass from being too brittle.

The reasons why a homogeneous metal is unsatisfactory as a bearing will therefore be appreciated. Only such alloys as the bronzes and the white metals have the requisite properties.

It should be mentioned that the eutectoid, as shown in the first micrograph, is itself a combination of two constituents — 23% of it being alpha solid solution and 77% of it the delta compound, the latter having a Brinell hardness of approximately 550.

Composition of Gears

Gear wheel blanks, and particularly rear axle worm wheels for heavy trucks and coaches, have been made from phosphor bronze for many years and much experimental work and service experience has shown that this alloy is the most suitable for the duties. The only other alloy which has been used in any appreciable quantity for this duty is the 10% aluminum bronze. This — in the form of die castings — was used in England for the worm wheels of

Patch of Alpha-Delta Eutectoid in 12% Tin Bronze at 750 Diameters

a popular one-ton truck with generally satisfactory results. However, the surface stresses (due to the large size of wheel employed) were comparatively light. Experience has shown that the aluminum bronzes under the high surface stresses which can be used with phosphor bronze are liable to failure through seizure or partial seizure which leads to rapid wear. Particularly is this true if the mating worm shaft is slightly deficient in hardness or the lubrication in service is not ideal.

Little alteration in composition has taken place in recent years in the phosphor bronze used for these duties, although research work has clarified the views regarding the effect of various impurities, and fixed the changes in physical properties due to variations in tin and phosphorus content. Practically all the high grade worm gear bronze produced in England today is found to fall within the following limits of composition. It is fairly close to the American S.A.E. specification No. 65 for phosphor gear bronze.

Tin	10.5 to 12.5%
Lead	0.50 maximum
Zinc	0.50 maximum
Phosphorus	0.2 to 0.4%
Nickel	0.0 to 2.0%
Copper	Remainder

Limiting factor for tin is the decreasing tensile strength, ductility and particularly shock strength with increasing tin content above 10%.

For similar reasons the phosphorus content is now generally restricted to that amount which will insure good fluidity and founding properties; tin being preferred as an actual hardener to phosphorus. Phosphorus (in addition to its value as a deoxidant) is a powerful hardener, practically the whole amount remaining in the alloy forming copper phosphide — Cu_3P — which is associated with the alpha-delta eutectoid, as shown in the micrograph below. Copper phosphide is not a great deal softer than the alpha-delta eutectoid and is therefore valuable as a hard, load-bearing constituent. But its intrinsic brittleness is reflected in the lower impact values obtained from bronzes of high phosphorus content. That is, of two bronzes of the same hardness, the one containing the higher phosphorus is the more brittle.

Lead above 0.5% lowers the yield point in compression, and therefore the tendency to pitting (a type of fatigue failure) under high compressive stresses is increased.

Additions of nickel are of comparatively recent origin and have the effect of raising the

Ternary Eutectoid in Phosphor Bronze (11% Sn, 0.6% P) at 2000 Diameters. Black areas are alpha solid solution, white are delta compound, and the halftone stripes are copper phosphide

yield point in compression and thus the resistance to pitting. Nickel also raises the tensile strength and tends toward higher impact values. Its marked effect on the plasticity of the bronze necessitates the proportion of nickel — particularly in relation to the tin content — being carefully controlled, as a certain degree of plasticity is essential in a gear bronze as in any bearing metal.

Pouring a 500-Lb. Gear Blank Into a Centrifugal Caster

Casting Characteristics

The type of phosphor bronze used for worm wheels is, due to its high tin content, unsuitable for forging and hot working and therefore castings have to be employed. The greatest alteration which has taken place in the process of manufacture in recent years has been in the methods of molding and casting to secure improved physical properties without destroying or impairing the essential bearing structure. The constantly increasing efficiency of the automobile engine with greater torques and higher road speeds, coupled with the insistence on maintaining or even reducing existing gear sizes has compelled us to improve the quality of the materials.

Influence of Size and Process

Property	Method of Making Casting			
	Sand Cast	Ring Chill	Three-sided Chill	Centrifugally Cast
12-In. Blanks With 2-In. Face and 8-In. Bore				
Yield point, lb. per sq. in.	16,000	19,000	26,000	37,000
Tensile strength	30,000	33,000	38,000	44,000
Elongation	7%	4%	6%	7%
Hardness, 10 mm. ball, 1000-kg load	75	85	100	110
Izod impact, 20-mm. notched bar	34 ft-lb.	23 ft-lb.	17 ft-lb.	25 ft-lb.
Compression, permenent set at 50,000 lb. per sq. in.	6.8	4.50	2.9	2.6
Density, corrected	8.40	8.50	8.65	8.75
18-In. Blanks With 3½-In. Face and 12-In. Bore				
Yield point	14,000	15,000	23,000	31,000
Tensile strength	26,000	30,000	34,000	41,000
Elongation	5%	5%	7%	9%
Hardness	63	78	85	98
Izod impact	38 ft-lb.	29 ft-lb.	24 ft-lb.	34 ft-lb.
Compression	8.2	5.8	4.2	3.5
Density	8.20	8.30	8.45	8.60

For worm wheels the ordinary sand casting has many deficiencies. Probably the greatest of these is the low density consequent on slow cooling through the solidifying range. This was early recognized and most manufacturers long ago adopted some form of chilling for the tooth portion of the blanks. The maximum density of a 12% phosphor bronze is about 8.85 but the sand cast material varies from 8.25 to 8.45 dependent on the size of the blank and the casting temperature (that is, on the rate of solidification). This partial porosity is reflected in poor physical properties in other directions; hardness, tensile strength, compressive strength all being considerably below the maximum of which the alloy is capable. Sand castings are also frequently variable in properties throughout the mass, particularly where varied sections are encountered. Spongy metal is frequently found in heavy bosses and in the vicinity of runners and risers.

First efforts to improve the material resulted in a ring chill to densen the periphery of

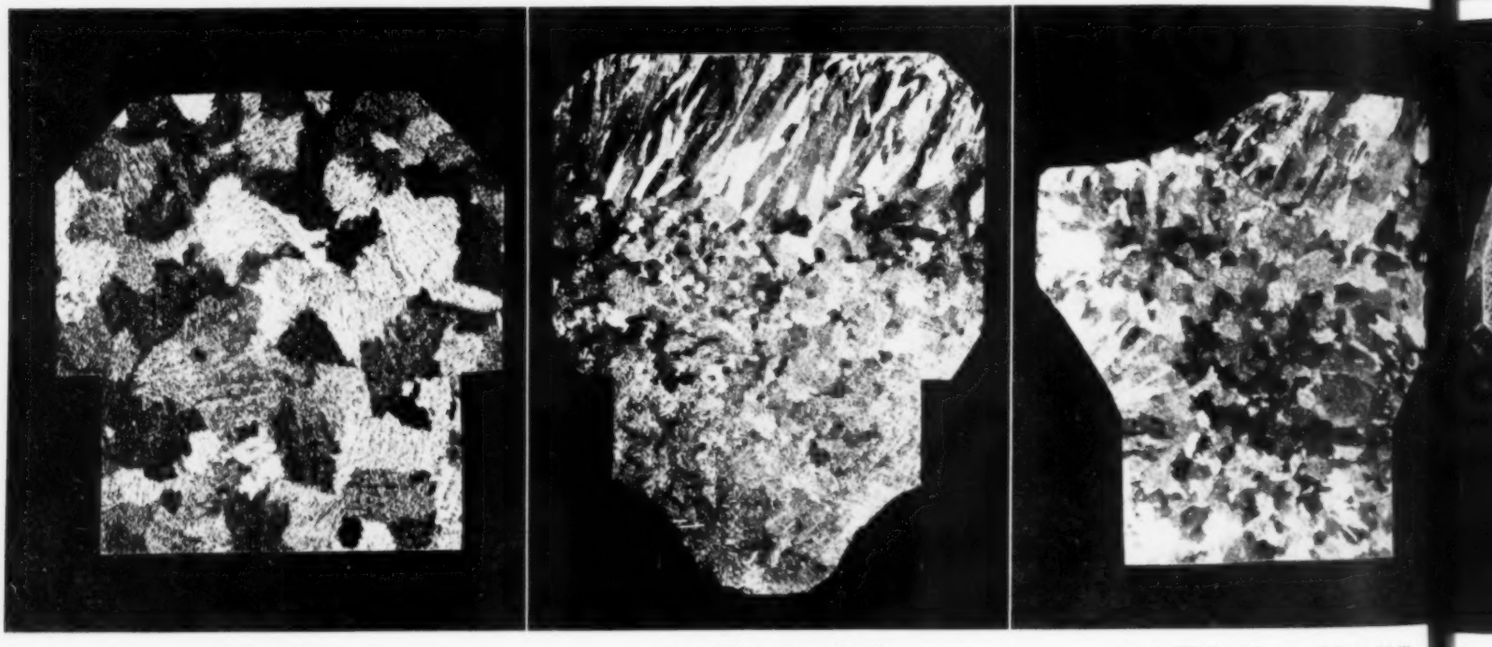
the blank. This was certainly an improvement but brought certain disadvantages in its train. Primarily the tooth portion was densified at the expense of the other portions of the wheel which were generally left in a condition something worse than a plain sand casting, as can be seen by the macrographs below.

Ring chills also had a deleterious effect on the bearing structure of the bronze in that portion of the blank subject to the influence of the chill. The chilled portion was generally deficient in alpha-delta eutectoid, with a corresponding increase of tin in the solid solution matrix. This circumstance was due to the peculiar rate of cooling obtaining with a ring chill in a sand mold, and was equivalent to the effect of a partial annealing. (Any subsequent annealing of a cast phosphor bronze in the temperature range of 950 to 1300° F. results in partial absorption of the essential eutectoid into the matrix.) Neither did the ring chill do away with the necessity for heavy risers to secure adequate feeding, except in light sectioned wheels. Indeed the greater speed of solidification and higher liquid shrinkage usually meant these had to be increased.

Three Sided Chills

The next step forward was to chill the blanks on both top and bottom faces and periphery, the method generally described as the three sided chill. This process is in common use today, and whilst it gives results superior to those of the preceding methods, still falls short of the maximum obtainable. Its main disadvantage is the difficulty of compensating for the liquid shrinkage, particularly in heavy or complicated sections. To overcome this, partially, high casting temperatures must be used (which lengthen the time of freezing) and these result in castings having a larger grain size and lower density than the best obtainable. These deficiencies are again reflected in the other physical properties. The difficulty of securing absolute soundness in large or complicated designs is also considerable.

The centrifugal method of casting, if prop-

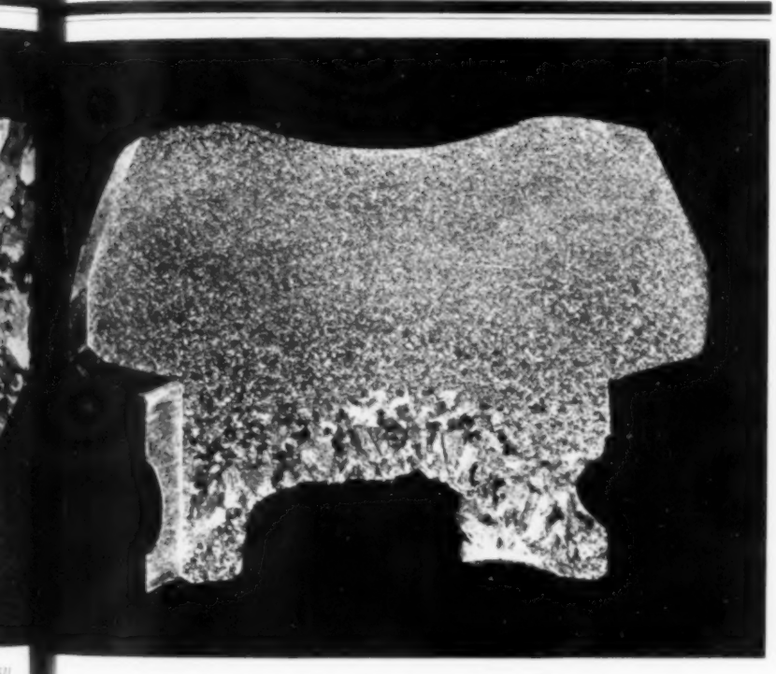


Sand Cast *Cast With Ring Chill* *Cast With Three Sided Chill*

Macrostructure (Actual Size) of Bronze Gear Blanks Cast in Stationary Molds

erly conducted, overcomes practically all the deficiencies in the other methods and gives the nearest approach yet obtained to the maximum physical properties of the alloy.

For gear wheel blanks the mold is best rotated with a vertical axis (as opposed to the more usual horizontal axis employed for plain cylinders and pipes). The composite parts of the mold are of steel and the inner part of the blank is formed with a sand core. Metal enters the mold proper through orifices in this core. Peripheral speed found most suitable varies somewhat with the diameter of the blank, approximately 1600 ft. per min. being appropriate for blanks 8 to 10 in. diameter and 2400 ft. per min. for blanks 5 to 6 ft. diameter — the largest yet cast by David Brown & Sons.



Centrifugal Casting Produces Much Smaller Grains in Metal Where Teeth Are to Be Cut

Advantages of New Method

Superiority of the centrifugal casting over the best method prior to this, that is, the three sided chill, is mainly due to two causes. The constant agitation and vibration during the whole period of solidification results in a very small grain size. The grains being small and oriented at random, it follows that the dendrites are short. This gives the strongest structure.

The other main factor is that compensation for liquid shrinkage (in foundry parlance "feeding") is done under the considerable pressure due to centrifugal force. This overcomes the biggest difficulty in rapid solidification, and results in a phosphor bronze gear casting whose whole cross section has a very high and practically uniform density.

Difference in uniformity and high physical properties between this and other methods becomes particularly marked as the weight and section of the castings increase, as shown in the tables for castings 12 in. diameter by 2 in. face and 8 in. bore, and for castings 18 in. diameter with 3½ in. face and 12 in. bore. (The table mentioned is on page 17.) The smaller size is typical of castings used for back axle worm wheels for five-ton trucks, and the larger one is the heaviest that would be used in the British truck industry. These are average values and include (particularly in density and hardness) the whole cross section of the wheel. The small difference that mass makes to the centrifugal casting will be observed, and this is one of the valuable features of the process and particularly helps the designer, since one set of stress figures can be used.

Typical macrostructures showing the grain size of blanks cast by different methods are also shown, representative of the particular method, done in a manner likely to secure the highest proportion of satisfactory castings.

To appreciate fully the advantages of the centrifugal casting process, it is really necessary to have experience of all methods of casting over a period of time and with a wide variety of sizes and sections. The general similarity of high quality product over a varied range produced by the centrifugal process then demonstrates, in factors not easily translatable into figures, the definite advance in bronze founding represented by this process.

By John G. Mapes
Managing Editor
The A. S. S. T. Review

STEEL PARTITIONS

present and future possibilities

METAL is catching up on non-metallics as material for interior partitions for offices and industrial buildings, just as it has already caught up to them and far exceeded them as framework for large buildings. Somehow the fact that bricks and mortar were discovered by the ancients before they learned about metals has delayed in more than one instance the fullest utilization of the properties of metals, even by modern men.

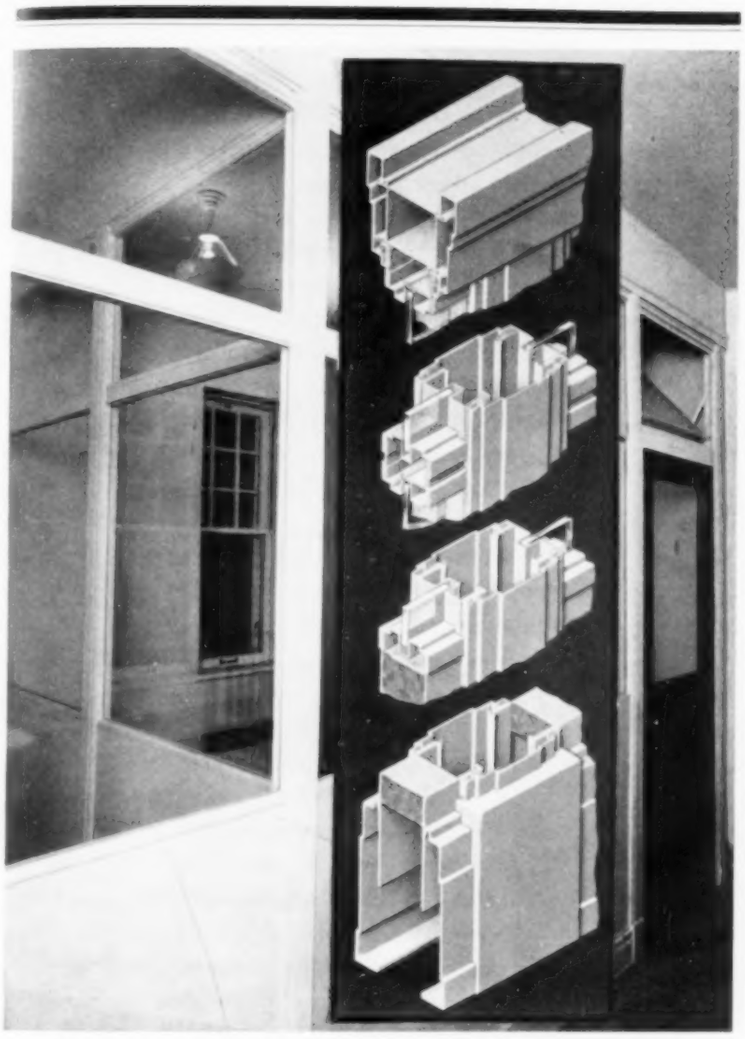
But in spite of a reluctance to *try* anything new and difficulties in getting the building trades' unions to *do* anything new, builders and owners have gradually become convinced of the advantages of metal partitions, and today about 50 companies, large and small, are making them. In the neighborhood of 10,000 tons of sheets is the normal yearly consumption.

As an illustration of what is being done, the methods used by the Mills Co. of Cleveland may be cited. Full finished, furniture grade sheet steel is used, previously stretcher leveled. Thicknesses range from 20 to 16 gage. Manufacturing operations are simple — special rolls form the connecting edges of the sheets into mortises and tenons which are then crimped into tight fit. Additional rigidity is secured by friction clips which have been so designed as to be completely interchangeable throughout the various parts of the partition such as corner posts, vertical or horizontal members, tee and angle joints. The engraving on the opposite page indicates that rather intricate details can be shop fabricated in this manner, by the ingenious use of a relatively small number of standardized details.

Standard and special panels are completely assembled in the shop as separate units by crimping together the mortises and tenons. When the panels arrive on the job it is only necessary to place them in proper position, fasten them tightly with the regular steel clips, and snap on the ornamental cap which completes the hollow post between adjacent panels. (This hollow center is often used to carry electric wiring.)

Almost any specification as to finish can be met. Many of them are imitative in character, such as marble, wood, or plaster. Others, like the dull olive green paint for industrial partitions, are merely practical. One limitation is imposed by the fact that the sheets are not smooth enough to carry a gloss coat without emphasizing their waviness, and customers find this distracting.

Ingenious is the method used to give the



Furniture Grade Sheet Formed Into Sub-Units and Crimped and Snapped Together Build up Rigid Metal Partitions

rough plastered effect for flat walls shown on page 22. Two coats of a neutral colored paint are applied, following which fine white lake sand is sprayed on with an air gun. A third spray of paint serves to bind the sand in place and then even a close examination will fail to distinguish between a lath-and-plaster wall and its sand-and-metal competitor.

Tile partitions are inherently more resistant to the passage of sound than a sheet of steel, but almost all opaque metal partitions used in offices are of the double wall type with a 2-in. air space. The Mills Co. provides additional insulation, as effective against heat as against sound, by filling the air space with laminated fiber with the cells running in two directions. This is essentially the material used in the more expensive refrigerators.

To make the partitions even better sound-killers, it would be necessary to run strips of felt between the edges of the partition and the floor, walls, and ceiling of the building proper.

The "cold" feeling of metal, caused by rapid conduction of heat, is no drawback to partitions, as it is to metal furniture, as the former are seldom in contact with the skin.

In the face of these advantages, however, brick or tile walls are still paramount in office buildings. Strangely enough, neither of the two tallest buildings in the world was designed by the architects for metal partitions, although both were heralded as the ne plus ultra in modernity. Such steel partitions as are installed have been used for subdividing the rented units.

This unfortunate reluctance to try something comparatively new like a steel wall can gradually be overcome by the same kind of diligent selling which finally brought metal lath and welded pipe joints into more equal competition with more conventional materials. Reduction in over-all cost is the most powerful argument. Added advantages for a higher price are more difficult to sell to nearly anybody, these days.

In this respect, one of the great selling points of the metal partition has been economy. First cost and installation are practically the same as a plaster wall. Maintaining metal partitions is cheaper for the obvious reasons of fewer repairs and a more easily washed surface. It is in the salvage value that the metal partition is so far ahead of the non-metallic wall that the competition ceases to be close.

Wastage in brick and tile partition is enormous: For 1926 the National Association of

Building Owners and Managers reported that $15,000,000 was spent to tear out and junk office partitions. Metal walls of unit construction, on the other hand, can be moved, rearranged, re-erected, or even stored against future needs without a dusty mess of brick and plaster.

Future Extensions

Some day these advantages will be appreciated by the home owner. As a matter of fact, residence construction is a field into which metals have penetrated with great difficulty. Even up to a few years ago, heating and plumbing equipment was about the limit, except for light hardware. Now that mechanical refrigeration machines and washers are in more or less general use, to say nothing of all sorts of electrical devices, the metallic content of the average house is far greater, and this trend heartens those who are promoting metal cabinets, metal sash, monel or stainless sinks, and so on.

Movable metal partitions should be as desirable in a home as in an office, for requirements as to room size certainly vary with families over a period of years. At one time a larger living-room may be more desirable than a large dining-room and kitchen, while later the converse may be true.

With present building practices, movable metal partitions cannot be used in homes, for the subdividing walls now support the upper floors. METAL PROGRESS, in July, 1931, summarized the adoption of metal by the modern school of architects, particularly the functionalist group who want every component part of a building to have some purpose besides mere decoration. They see no reason why, in a home of average size, floors and ceilings should not be self-supporting, inasmuch as to make them so merely requires the use of materials already available, such as a little structural steel, and the disregard of a few superannuated methods of construction.

Metal Partition May Be Finished so Like Plaster That Close Inspection Fails to Reveal the Difference

Architectural Changes

The type of metal partition used in offices today may or may not be applicable for home use. Only Mrs. Housewife can say definitely whether she wants her walls made of steel and finished to look like steel, or wood, or plaster, or marble, or whether a steel wall feels too cold. This market does not now exist, but the Century of Progress Exposition has opened in Chicago, and millions of Americans will see there an entirely new style of architecture in which metal plays a leading role, in little buildings as well as big, not only underneath the surface but out in the open. If this exposition has as much influence upon future building design as did the World's Fair in Chicago 40 years ago, the market for metal as a home building material is going to develop before even the functionalists thought it would.

By T. S. Fuller
Metallurgist
General Electric Co.

ENDURANCE

of metal in corrosive surroundings

SINCE METALS have been used for structures or machines whose members are subjected to repeated stresses, failures have occurred which appear to be characteristic of brittle substances, rather than tough metal. As the stresses involved have become greater and as speeds of machines have been increased, with the consequent increase of the frequency of application of stress, the problem of avoiding such breakdowns has become more acute.

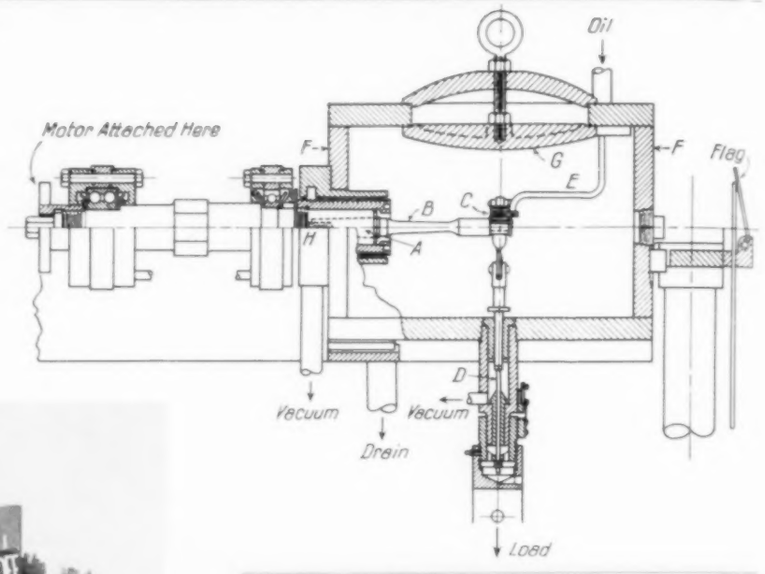
It was in 1859 that August Wöhler (whose work was published in *Engineering*, London, in 1871 as the first comprehensive treatise on endurance) began his investigation of the phenomenon under the auspices of the Prussian State Railways. The study has been continued by many others.

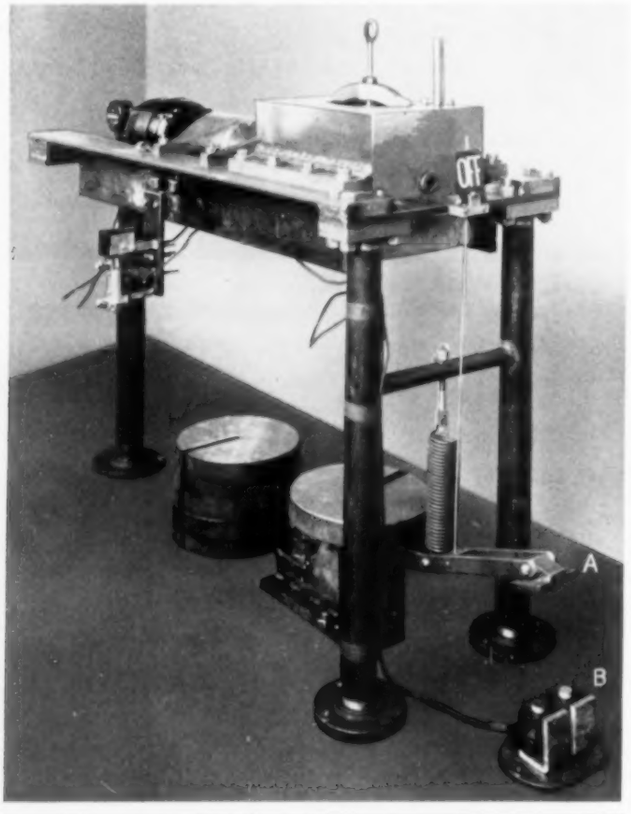
In 1914 the World War with its multitude of ramifications made an intensive study of endurance phenomena not only highly desirable but essential. Since that time the work of Prof. H. F. Moore of the University of Illinois has helped to make understandable the fundamentals of this subject. His book, "The Fatigue of Metals," written in 1927 with J. B. Kommers as co-author, may well be consulted.

"Endurance" and "fatigue failures" are terms applied to fractures resulting from the application of repeated stresses. Any type of tension, compression, or shear stress (or combination of simple stresses) may be involved, in magnitude including repetition from zero to a positive maximum, from a positive minimum to a positive maximum, from a negative minimum to a positive maximum, from a negative minimum to zero, and so on. Most laboratory tests in America, however, have been carried out on turned specimens arranged as rotating beams where the unit stress at any one point passes alternately during each revolution from maximum tension through zero to maximum compression. Work involving torsional stress is in progress at the National Physical Laboratory in England. Equipment is also available for stressing specimens in direct tension and compression over the entire cross-section.

Since the subject matter of this article has to do with endurance of metals in corrosive atmospheres or surroundings, a type of equipment suitable for making tests in controlled environment will be illustrated. The assembly drawing and photograph on the next page is of a modified White-Souther and McAdam type of rotating beam machine, used in the research laboratory of General Electric Co. for testing the endurance properties of various steels in steam at different temperatures and pressures. Of course, the same machine is entirely suitable

Each Fatigue Testing Machine Is Driven Directly by an Individual ½-Hp. Motor, Running at 2200 R.p.m. Specimen B is held by the rotating holder A inside the steam box F, which is closed at the top by an elliptical cover G. The load is applied by dead weight to the specimen through the rod D and bearing C. E is an oil pipe leading from the lubrication system to the bearing C. Steam is admitted through an inlet, not shown. Steam packings are placed around the rod D, and the rotating shaft at H, from which water is drained by a vacuum





for making tests in air or media other than steam.

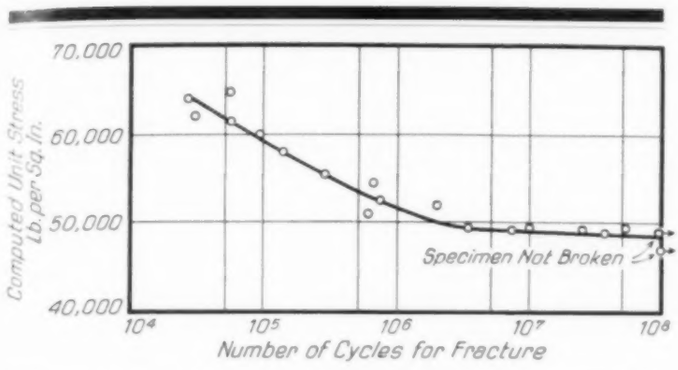
After the specimen is mounted and the motor started, the load is applied by depressing the foot pedal to contact with the electromagnet on the floor; the winding of the magnet is connected in series with the motor. This releases the support under the weight that constitutes the load, and the load remains hanging on the end of the specimen until the motor circuit is opened, either intentionally or by loss of power, whereupon the electromagnet immediately liberates the pedal and the load is removed from the specimen by the heavy spring.

The specimen suitable for this machine has a reduced section similar to McAdam's "type C" specimen described in 1921. When it is arranged as a rotating cantilever beam the maximum stress is in a plane whose diameter is 0.4687 in., although stress from the shoulder over a distance 1½ in. therefrom varies only by 1½%.

S-N Diagram and Fatigue Limit

To investigate a metal or alloy a number of test pieces are prepared, as nearly identical in condition as possible. The first one is run at a load that is expected to cause failure in a comparatively short time. Successive runs until failure are then made at successively smaller loads, until a load is found that will not cause failure after a long time — usually the test is stopped somewhere between 10 and 100 million reversals. The data, therefore, are a series of stress-cycle relationships, each one of which is sufficient to cause failure.

Although other methods may be used, it is customary to plot stress value to Cartesian coordinates and corresponding numbers of cycles to logarithmic coordinates, and a line joining them up has come to be known as the "S-N diagram." Such a diagram is shown on the next page. It



Relation Between Stress and Number of Applications for Failure ("S-N Diagram") for a Steel Containing 3.3% Ni, 0.9% Cr and 0.25% C, Heat Treated to 140,000 Lb. per Sq.In. Tests made in dry air at room temperature. (Moore & Kommers)

will be observed that under the conditions of that experiment, S.A.E. 3425 will withstand indefinitely a stress ranging from 18,000 lb. per sq.in. in tension to a like stress in compression. Moore and Kommers have defined the endurance limit or fatigue limit as: "A unit stress below which the metal will withstand an indefinitely large number of cycles of stress without failure." The endurance limit value bears no relation to the proportional limit, but for steel is usually 40 to 60% of the ultimate strength.

The first published record of the phenomenon which has since come to be known as corrosion fatigue was in a paper by Haigh before the British Institute of Metals in 1917. In this paper, which dealt with the fatigue of brasses, attention was called to the fact that fatigue occurs under lower stresses when the conditions tend to promote corrosion. Strangely enough, the phenomenon was thereafter very largely disregarded until 1925, when (simultaneously and quite independently) work was begun by D. J. McAdam at the United States Naval Experiment Station at Annapolis, and in England by G. D. Lehmann under the auspices of the Air Ministry. Papers from both sources were published in 1926, McAdam's in particular being the first of a long line destined to set forth the principles of corrosion fatigue. A very helpful summary of this important subject has been given by Dr. H. J. Gough in his 1932 Autumn Lecture before the British Institute of Metals.

Any discussion of the subject in its present state must necessarily refer frequently to McAdam, whose work has furnished a very large part of the data which have helped to clarify a difficult and extremely complicated phenomenon.

He has defined corrosion fatigue as "the entire process that results in complete failure under corrosion and cyclic stress of high frequency." The definition would perhaps be more accurate if the words "of high frequency" were omitted, it being quite certain that failures occur that are due to the combined effects of corrosion and repeated stress of very low frequency.

Whenever corrosion fatigue exists there must be involved at least four factors; namely, (1) stress, (2) medium surrounding the specimen, (3) temperature, and (4) cycle frequency. The surface condition of the stressed member is also well understood to be of very great importance. Tool-marks, scratches, shoulders, keyways, or sudden changes in section of any kind cause a marked lowering of fatigue limits.

Corrosion Fatigue Limit (N)

The earlier work on corrosion fatigue seemed to indicate a definite value called by McAdam the "corrosion fatigue limit" for each metal tested under carefully specified, mildly corroding conditions. More recent work on monel metal, however, has led McAdam, and later Gough, to doubt the existence of such a well-defined value. The later view is the most reasonable when analyzed in the light of the many variables involved.

Tests on monel metal in a stream of fresh water carried out by McAdam to 100 million cycles when plotted suggested a definite value for the corrosion fatigue limit. Further tests carried out by him to a billion cycles showed that somewhere between 1×10^8 and 1×10^9 cycles the S-N curve again turned downward.

This circumstance has led Gough to suggest the term "corrosion fatigue limit (N)," where N represents the greatest number of cycles endured in the test to which any given data refer. However he specifically stated in the lecture above mentioned that the present use of the term "corrosion fatigue limit (N)" "must

not be taken to indicate that a definite 'fatigue limit' exists under the stated conditions of test."

This is in agreement with an earlier statement by McAdam: "The 'corrosion fatigue limit' proved a valuable preliminary index of the behavior of metals under corrosion and cyclic stress. By means of corrosion fatigue limits, some of the most important characteristics of stress corrosion were established. It was shown, for example, that corrosion fatigue depends chiefly on the corrosion resistance, and is little influenced by variations in physical properties whether these variations are due to composition, heat treatment, or cold working. It was also shown that the corrosion fatigue limit is practically uninfluenced by size of cross-section, at least for diameters between ½ and 2.3 in. The corrosion fatigue limit, therefore, is of value in making a rough comparison of the behavior of metals under stress corrosion. It cannot be used directly as a basis for design. The behavior of metals under stress corrosion cannot be represented by any single numerical index."

In tests on the properties of steels in steam, performed at the research laboratory of the General Electric Co. and reported to the 1931 convention of A.S.S.T., examples of the effect of liquid water and oxygen are to be found. The air room temperature endurance limit ($N = 5 \times 10^7$) of a nickel steel of the 3.5 nickel, 0.35 carbon type, having an ultimate strength of 119,000 lb. per sq.in., was found to be 58,000 lb. per sq.in. In a test, however, in which a jet of wet steam was allowed to play upon the stressed portion, some liquid water forming in the presence of ample oxygen from the atmosphere, the corrosion fatigue limit ($N = 5 \times 10^7$) was found to be 24,000 lb. per sq.in.

A subsequent test on specimens in the steam box (air being excluded, and therefore very little, if any, opportunity for condensed moisture in the presence of steam at 100° C. and 0 lb. pressure) returned the endurance limit to its original value of 58,000 lb. per sq.in.

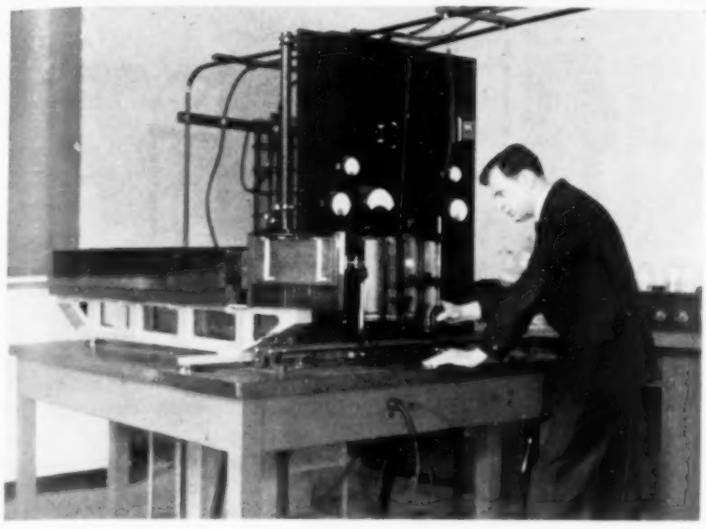
It has been emphasized many times in the literature that the effect of corrosion plus stress is far more damaging than the effect of corrosion alone followed by stress. This is well illustrated by values for nickel steel taken from the experiment in steam previously cited. Specimens which had been exposed to the action of wet steam and air for a period of one week showed an endurance limit ($N = 10^7$) of 50,000 lb. per sq.in. when tested in dry air. This value may be compared with the above mentioned values. Other specimens of this nickel steel pre-corroded one week in an atmosphere of wet steam and air and tested under a steam jet showed corrosion fatigue limit ($N = 5 \times 10^7$) value of 14,000 lb. per square inch.

The data secured by M. D. Collins and the writer on the stainless irons and steels in air and wet steam at various temperatures are summarized in the data sheet published in METAL PROGRESS for July, 1931. To these may be added data secured by Inglis and Lake for an 18-8 (carbon less than 0.16%). In the fully softened condition it had an endurance limit ($N = 2 \times 10^8$) of 39,400 lb. per sq.in., whereas in river water the corrosion endurance limit ($N = 1 \times 10^8$) was 25,000. After heating 60 min. at 1200° F. the later value ($N = 1.5 \times 10^8$) became 14,500.

Values for chromium-iron alloys secured by McAdam are given in the adjoining table. The figures in parenthesis represent (N) in units of 1×10^7. In other words, the corrosion endurance limit (N) of low carbon chromium-iron in fresh water is 43,000 ($N = 5 \times 10^6$).

Corrosion Fatigue Limits of Chromium-Iron Alloys [McAdam]

Material	Composition		Condition	Ultimate Strength	Endurance Limit ($N \times 10^7$)		
	Cr	C			In Air	In Fresh Water	In Salt Water
Stainless steel	14.50	0.38	Quenched and drawn	117,400	54,000 (2)	37,000 (1)	27,000 (3)
Low carbon stainless steel	12.90	0.11	Annealed	89,500	56,000 (2)	38,000 (1)	27,000 (2)
Low carbon chromium iron	17.09	0.14	Annealed	87,700	47,000 (1)	43,000 (0.5)	26,000 (3)
High carbon chromium iron	17.74	1.20	Annealed 1700°F.	107,000	60,000 (1)	37,000 (0.5)	25,000 (1)
Chromium-copper-iron	20.94	0.19 Cu 0.92	Annealed	87,900	47,000 (0.6)	41,000 (3)	30,000 (2)
27% chromium iron	27.37	0.20	Annealed	81,000	44,000 (0.4)	39,000 (0.4)	30,000 (2)



By F. E. Roach
Perkins Observatory
Delaware, Ohio

analyzing steel with SPECTROGRAPH

TRANSFER of spectroscopic methods from science into industry has been rather tardy. Pioneer workers in the field sensed its great potentialities in the detection of minute quantities of an element by the observation of characteristic lines in the spectrum. After the use of the modern photograph had become general it might have been thought that interest in the spectroscope as an analytical tool would have increased, but only a very few investigators devoted themselves to this study. Fascinating problems in atomic structure, which the study of spectra revealed, were occupying almost the entire attention of experts.

Of late years an acceleration in industrial uses may be noted so that today most research laboratories dealing with the properties of metals have well-equipped spectroscopic divisions and, indeed, in many cases it has been found that routine control analyses may be advantageously carried out by their aid.

The principles of practical spectrum analysis are not in any sense abstract or complicated. They may be stated as follows: If the spectra of a number of samples of a metal containing varying amounts of an impurity are examined, it will be found that the lines due to the principal constituent are constant in position and intensity. They serve as the reference points for locating the lines caused by the impurity or minor constituent. As a rule, the intensity of these latter lines increases as the amount of impurity increases. This general rule forms the basis of an empirical relationship between composition and line intensity.

In practice any one of a number of methods for measuring the intensity of a spectrum line may be employed. One that has been successfully used by the writer in the research laboratory of A. O. Smith Corp., Milwaukee, for analyzing impurities in steel and other metals is known as the logarithmic sector method, and will be described.

A convenient means of obtaining a spectro-

gram is indicated by the first diagram. Two rods of the sample to be tested are used to strike an arc, the light of which is concentrated on the slit of the spectrograph by a condensing lens. This pencil of light is broken up into its constituent colors, or lines, by a prism, and brought to a focus on the photographic plate. The essential equipment therefore is the arc, the spectrograph, and a dark room. None of these need be very expensive to be quite useful.

When a logarithmic sector is used it is placed directly in front of the slit. During the exposure it is rotated in front of the slit, causing the effective exposure to vary progressively along the length of the slit. The spectrum lines then appear on the developed plate not as lines of uniform intensity along their length but as wedges which fade out. (This is illustrated in the sketch.) The measure of each line's length then becomes a direct indication of its intensity.

As an instance of how the spectra may be interpreted, the sketch contains some of the important iron and chromium lines. (The latter have a dot placed below them for easy identification.) Attention is called to the increase of height of the chromium lines as the chromium content increases from nothing to 1%. The lower spectrum, of "pure" iron, does not show these lines at all, from which fact it is inferred that chromium is not present.

In practice it is found convenient to compare the "impurity" lines with adjacent iron lines. In this way any slight changes in the experimental conditions do not affect the accuracy of the determination, as all lines on a single exposure respond equally.

Length of lines may be measured with a low power microscope having a graduated scale in the focus of the eyepiece. It is found that different observers will not agree exactly on the absolute length of a given tapered line, but in spite of this, independent measures of the *difference* of length of any two such lines, which comprise the data necessary for the analysis, will usually agree within 0.2 mm.

A typical calibration curve shows the percentage composition plotted against the difference in length of two selected lines, one due to the principal constituent (iron) and the other to the "impurity" (chromium). In the example illustrated the two lines chosen happen to be the eighth and ninth lines from the left in the diagram opposite.

This procedure is readily seen to lend itself to rapid analyses as a number of impurities are recorded on a single plate and the analyst is able with practice to locate and measure their respective lines within a reasonably short interval of time. If the utmost speed is desired the plate can be ready for measurement within about 5 min. of the time it was exposed, by using a rapid developer and fixing bath. Measurement may be carried out while the plate is still wet.

By the above method the following minor constituents of steel can be quantitatively estimated: Chromium, manganese, silicon, titanium, nickel, vanadium, tin, and copper. At present the practical upper limit within which accurate results can be expected may be placed at about 2%. The lower limit varies with the element in question and, to some extent, with the lines chosen. Most of the elements mentioned can be determined to 0.001%. Some analyses can be carried even lower by extrapolating the calibration curves.

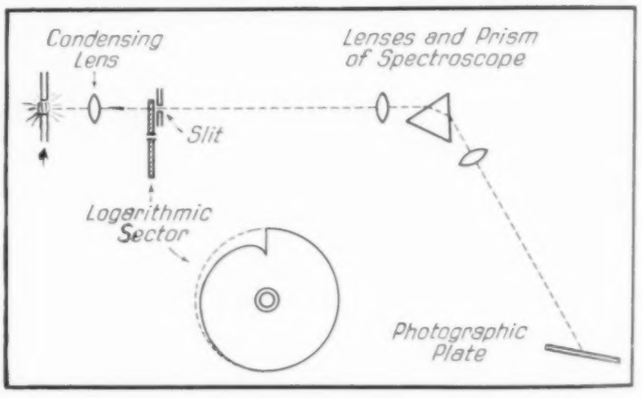
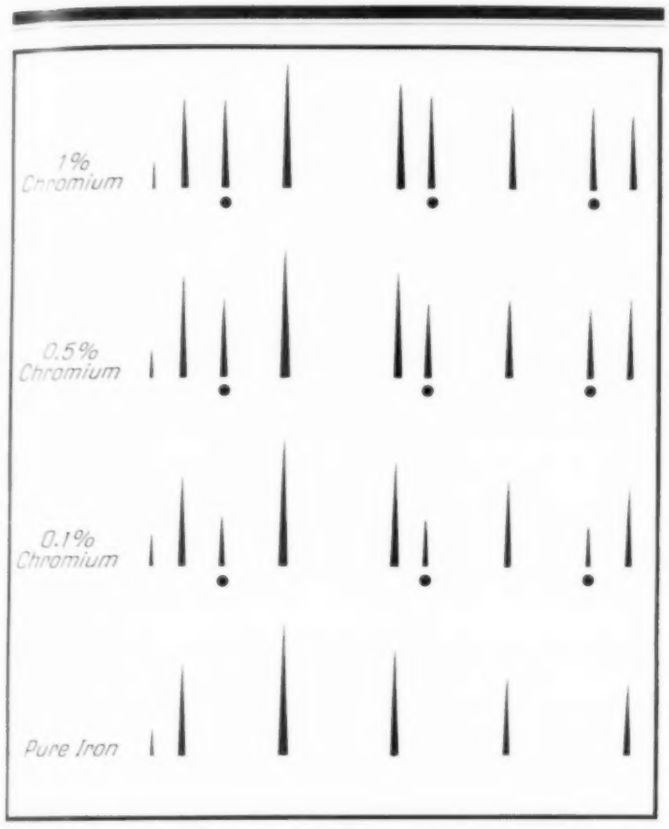


Diagram of Optical System. Shape of the logarithmic sector is also shown

Phosphorus and sulphur cannot be detected in the small amounts in which they occur in steel, due to the weakness of their lines. Carbon presents difficulties of a different nature which may be overcome in the future.



Variation of Spectral Line Intensities in Steel Samples. Note how the iron lines are constant in length, whereas the chromium lines (marked by dots) increase in length with a continual increase in the alloy content

Problems often arise in which a mere knowledge of the presence or absence of certain impurities in a metal gives the required information. Here the spectroscope can render very valuable aid. Unsuspected impurities are often found in this manner which would require considerable labor to locate by chemical methods. If the analytical chemist has to make a 100% analysis of an unknown he can to good advantage be guided by the spectroscopic analysis.

Recent developments make it feasible to study solutions, which greatly enlarges the field of usefulness of the method, and has proven especially valuable for zinc and zinc alloys.

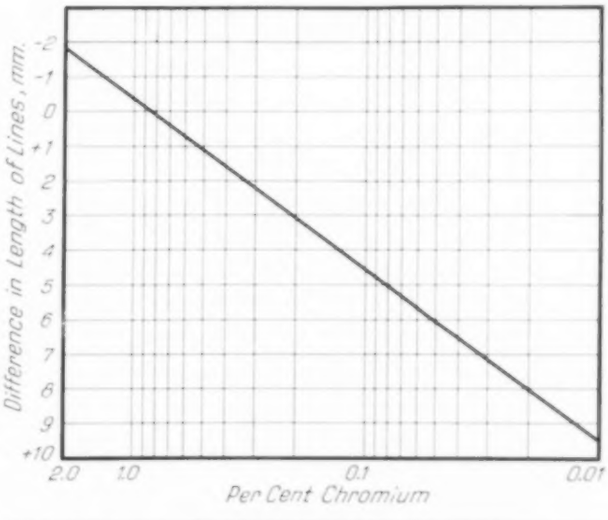
Occasionally certain impurities are segregated in the sample. Since by suitable methods a very small specimen can be studied, the nature of these segregations may often be determined by the spectroscope. This type of analysis is termed "local" or "topographic analysis." Numerous other applications in which the spectroscope is able to give important information will arise.

The type of spectrograph best suited to any particular type of work must be determined in each case. Since it is necessary to employ the ultra-violet portion of the spectrum the optical parts must be made of quartz.

Two types of instrument are in general use. In one the entire spectrum from red to ultra-violet is photographed on a single plate. In the other, of higher dispersion, several different adjustments and settings are required to include this range of wave lengths. For many studies the former type is large enough and it has the advantage in price. As a rule, the larger instrument serves a wider variety of uses and the extra cost is justified. Cost estimates will consequently cover a rather wide range, and are meaningless unless associated with some specification for performance.

The technique of operating a spectrograph can be learned by any intelligent and painstaking laboratory assistant. However, in the development of methods, experience and an understanding of the principles are required.

Representative Calibration Curve for Estimating Chromium in Low Alloy Steels



By Clair Upthegrove
Prof. of Metallurgical Engineering
University of Michigan

SCALING

at heat treating temperatures

A GREAT deal of interest has been manifested in the scaling of metals in recent years and attention has been repeatedly drawn to the loss of metal incurred in various heating operations. This effect has at times been emphasized to such a degree that other related but important effects have been partially obscured. In the heating of shapes where the ratio of the surface to the mass is very large — as in wire and sheets — the metal loss in itself becomes of great importance.

But formation of scale and the subsequent metal loss is closely related to the problem of maintenance of size on finish-machined parts and to the avoidance of non-uniformity in surface hardness. If a little too much scale is formed the part may be undersize and the result is loss of the material and the labor costs. If, on the other hand, the part scales less in the heating operation than is expected, then additional finishing costs are involved.

Thin scale may prove favorable to decarburization or the scale itself may affect the rate at which the heat is removed, depending upon the ease with which the scale is split off by the quenching medium. According to French "slight oxidation accompanied by good adherence, or heavy adherent scale such as might be expected on some alloy steels, tends to retard cooling even in water quenching. All oxide coatings become of more importance in less drastic quenching media in which the conditions tend to preserve the continuity of the coating." (*Transactions*, A.S.S.T., 1930, page 805.) Scaling resulting in pitting may still further complicate the quenching problem by increasing the gas adherence.

Reaction of furnace refractories with scale furnishes a further need for the control of furnace atmosphere. Necessary data for such control are now being accumulated.

In the January issue of the *Transactions*, Dr. Murphy and the author presented the results of a fundamental study of scaling of steel, a study sponsored by the Committee on Industrial Gas Research of the American Gas Association, and carried out at the University of Michigan. It considered the effect of temperature over the range 1000 to 2000° F. for four simple scaling agents: Oxygen, air, carbon dioxide and water vapor. The time factor, rate of flow and diluting agents were also studied.

Results of this investigation, while necessary to the complete understanding of scaling of steel, are not always easily translated to mixtures of gases such as occur in a gas-fired furnace. Its atmosphere may introduce the effect not only of nitrogen as a diluting agent but that of carbon monoxide and hydrogen as reducing agents and, with a very large excess of

fuel, even unburned hydrocarbons. As a step in the direction of connecting these data to the conditions existing in the complex atmospheres, results were also presented to show the effect of various combustion atmospheres at different temperatures on a low carbon steel.

It is my present plan to deal entirely with the effects of these various atmospheres, which are obtained by burning city gas with different air ratios on a number of the more common steels. Results given are for one temperature: 1700° F. The steels used are essentially those used by Murphy and Jominy in their studies of scaling at forging heat (2300° F.) reported in Engineering Research Bulletin No. 21, 1931.

The method of carrying out the tests is the same as that described in January *Transactions*. The samples, which are $2\frac{1}{2}$ in. long, 0.625 in. diameter, and finished with 00 emery, were introduced into an electric tube furnace in a stream of purified nitrogen; the furnace was brought to temperature, the nitrogen cut off, and the desired scaling medium (gas and air) turned on. One hour later the scaling atmosphere was cut off, nitrogen again turned on, and the sample quenched in distilled water. The sample was then stripped electrolytically and the loss in weight determined. Scale split off was also weighed, for a check.

Scaling tests at 1700° F. on five carbon steels are summarized in the first figure (lower left group). Space limitations prevent the publication of the numerical data. It may be said, however, that the atmospheres were obtained by burning city gas with air in ratios varying from about 1:5 to 1:$1\frac{1}{2}$. When gas analyses of the furnace atmosphere showed any free oxygen, there was no CO or H_2 present, and vice versa. Under our conditions, the latter two, when present, were generally found in approximately the same amounts.

A comparison of these curves with Murphy and Jominy's for scaling at 2300° F. points to some very significant facts. At 2300° F. the medium carbon steels scale most rapidly and the high carbon steels at a lower rate. At 1700° F. the same order of scaling is followed with low and high carbons more closely grouped.

As would be expected, the rate of scaling is very much decreased with temperature, the scaling losses in atmospheres varying from 15 to 0% CO being less than that in 40 min. at 2300° F. with an atmosphere carrying 12% CO. Scaling losses at forging temperature are reduced only about 30% on going from no carbon monoxide to 12%, and then 90% or more on going to 15% CO, while at 1700° F. a very appreciable reduction in scaling occurs with the presence of only 1% CO (with the possible exception of S.A.E. 1090 steel).

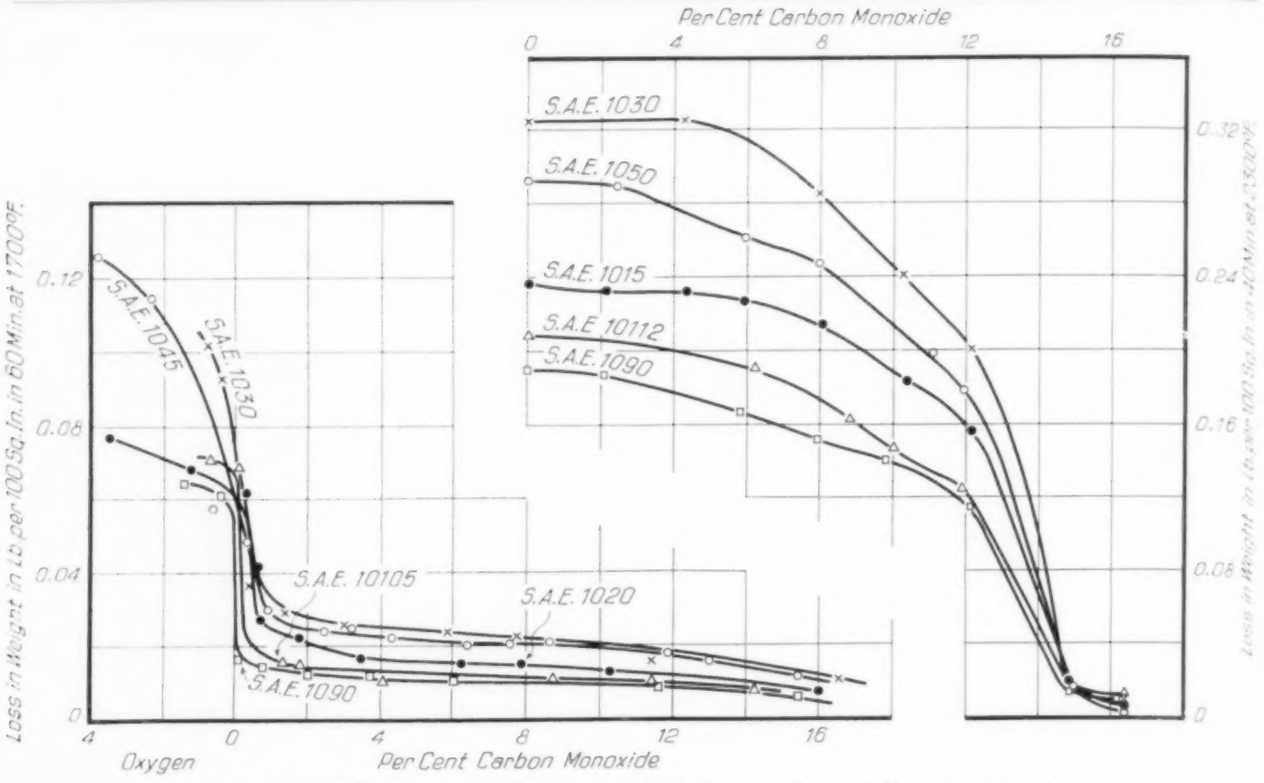
The 1020, 1030, 1050, and 10105 carbon steels all show a very definite tendency to increase in scaling rates as the percentage of carbon monoxide is decreased below 2%, with a much more marked tendency as zero is approached. With free oxygen present the tendency for further increases in the rate of scaling again becomes more pronounced between zero and 1%; the rate of increase in scaling falls off with further additions up to 1%.

This slowing down of the rate of increase of scaling with increasing percentages of oxygen, which appears to take place to a greater extent with the low and the high carbon steels than with the medium carbon steels, may account for the statements sometimes made that a furnace atmosphere carrying appreciable percentages of oxygen is "neutral" to a steel.

Blackburn and Cobb confirm this increase in rate of scaling due to the presence of small percentages of oxygen in the *Journal* of the Society of Chemical Industry, Vol. 49, p. 462T. Scaling effects on a low carbon steel at 1830° F. were measured as gain in weight. Adding 0.1% and 0.5% oxygen to the "neutral furnace atmosphere" carrying carbon dioxide, water vapor, and nitrogen, the sample gained 0.57 and 1.37 oz. per sq.ft. respectively, whereas 1% CO without oxygen caused only 0.21 oz. gain.

As indicated in the present work, the presence of 1% CO reduces very appreciably the scaling over that obtained in atmosphere approaching the "neutral type," and percentages of oxygen less than 1% may double or triple the scaling rate.

The effect of the various combustion atmospheres on the scaling of a group of alloy steels is quite similar to that observed for the carbon steels. The figure on page 33 summarizes and compares the results. An abrupt change is again observed in the scaling characteristics when relatively low percentages of carbon



Comparison of Scaling Loss of Five Common Steels, One Hour at Heat Treating Temperature (1700° F.) in Various Combustion Atmospheres — Lower Left — With Similar Data for 40 Min. at Forging Temperatures (2300° F.). Curves at right by Murphy and Jominy

monoxide are present, occurring over a somewhat wider range of atmosphere composition and at slightly higher percentages of CO.

The percentages of carbon monoxide required to bring about appreciable reductions are still very low when compared to the percentages required at 2300° F., where 10 to 12% CO was necessary to cut the scaling by half. At 1700° F., 3% CO prevents approximately three-quarters of the scaling of the "neutral atmosphere," and 1.5% insures a 50% reduction for all but the 4140 steel.

It will be observed that the scaling effects in the "neutral atmosphere" are not unlike those of the carbon steels. In atmospheres carrying higher percentages of carbon monoxide, the scaling effects for all five alloy steels are quite similar to those for high carbon steels. On the whole, the alloy steels maintain their same relative orders of scaling over the entire range. The effect of free oxygen in the combustion atmosphere on these alloy steels is apparently similar to its effect on the high and low carbon steels.

Attention has been called to the harmful effect of sulphur on numerous occasions. Murphy presented data before the A.S.S.T. convention last fall showing that it very materially increases the scaling losses in the forging range, and is appreciably absorbed by the steel.

Tests made in duplicate at 1700° F. indicate that the presence of sulphur again increases the scaling losses — though naturally to a much lower degree than at 2300° F. Enough to make 0.10 to 0.12% SO_2 was introduced into the fuel gases, which were burned to a complete combustion atmosphere. Losses by scaling after one hour are as follows: Steel 1020, 0.091 lb. per 100 sq.in.; steel 1045, 0.095 lb. per 100 sq.in.; steel 4140, 0.092 lb.; steel 3130, 0.082 lb. per 100 sq.in. Similar tests on 10105 steel in sulphur bearing atmospheres containing 4.1% CO and another containing 2.3% O_2 showed scaling losses of 0.071 and 0.107 lb.

Comparison of the above figures with the results shown on the curves for atmospheres free of SO_2 indicates that its presence has in all cases caused an appreciable increase in the rates of scaling. Differing from its behavior at 2300° F., SO_2 appears more active as an accelerator of scaling with an atmosphere of 4 to 5% CO than with either the complete combustion atmosphere or with 2% oxygen present.

In the presentation of the data, the percentages of oxygen or of carbon monoxide have been used as the criteria of the type of atmosphere. In addition to oxygen and carbon monoxide, all of these atmospheres carry water vapor and carbon dioxide as active scaling agents, and in the richer gas-air mixtures, hydrogen and (with the very high carbon monoxide contents) methane as non-scaling agents. Obviously the presence and effect of these various agents are related to the percentages of oxygen or carbon monoxide present.

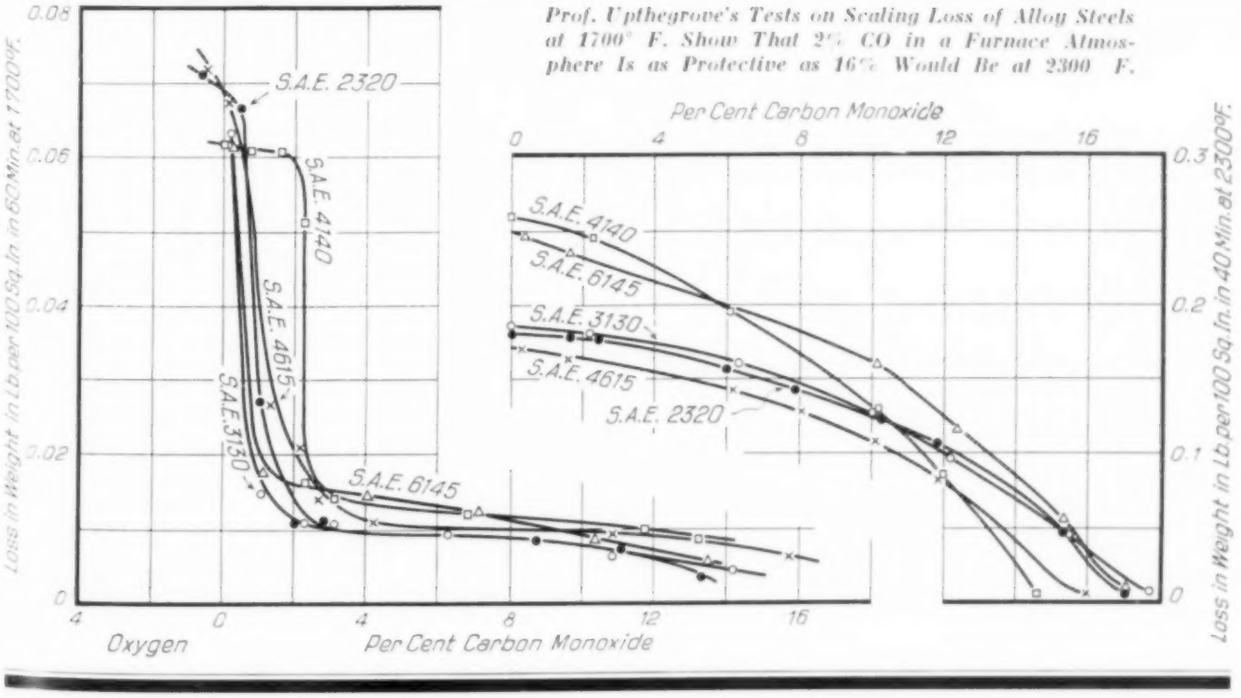
The various agents present, however, may have another effect and that is decarburization. Jominy, in Engineering Research Bulletin 18 (University of Michigan), 1931, has shown that moist hydrogen at 1600 to 1700° F. is a very effective decarburizer but that the effectiveness of carbon dioxide is greatly reduced by equal or greater percentages of water vapor; also that scale formation inhibits decarburization. While these are factors and effects beyond the scope of the present paper, it is necessary to recognize them in the final interpretation.

The significance of the effects of the changes in the character of the furnace atmosphere on the extent of the scaling of steel and its related effects can perhaps best be brought out by a few illustrations of the application of the data.

Consider, for example, a stress relieving treatment for a forging made of 0.45% carbon steel and weighing slightly over six pounds. Such a forging will approximate 100 sq.in. of surface. Assuming a temperature of 1700° F. and a time at temperature of one hour, the difference in the metal-loss when the forging is heated in an atmosphere which contains 2% oxygen and in one which contains 2% carbon monoxide becomes surprisingly large when expressed as thickness of metal.

According to the curves, a 1045 steel would lose 0.025 lb. per 100 sq.in. of surface in one hour at 1700° F. in the reducing atmosphere. This means a surface loss of slightly less than 0.001 in. In an atmosphere containing 2% oxygen, however, the same part will lose 0.11 lb. or 0.004 in. in thickness of metal. *(Cont. on page 62.)*

Prof. Upthegrove's Tests on Scaling Loss of Alloy Steels at 1700° F. Show That 2% CO in a Furnace Atmosphere Is as Protective as 16% Would Be at 2300° F.



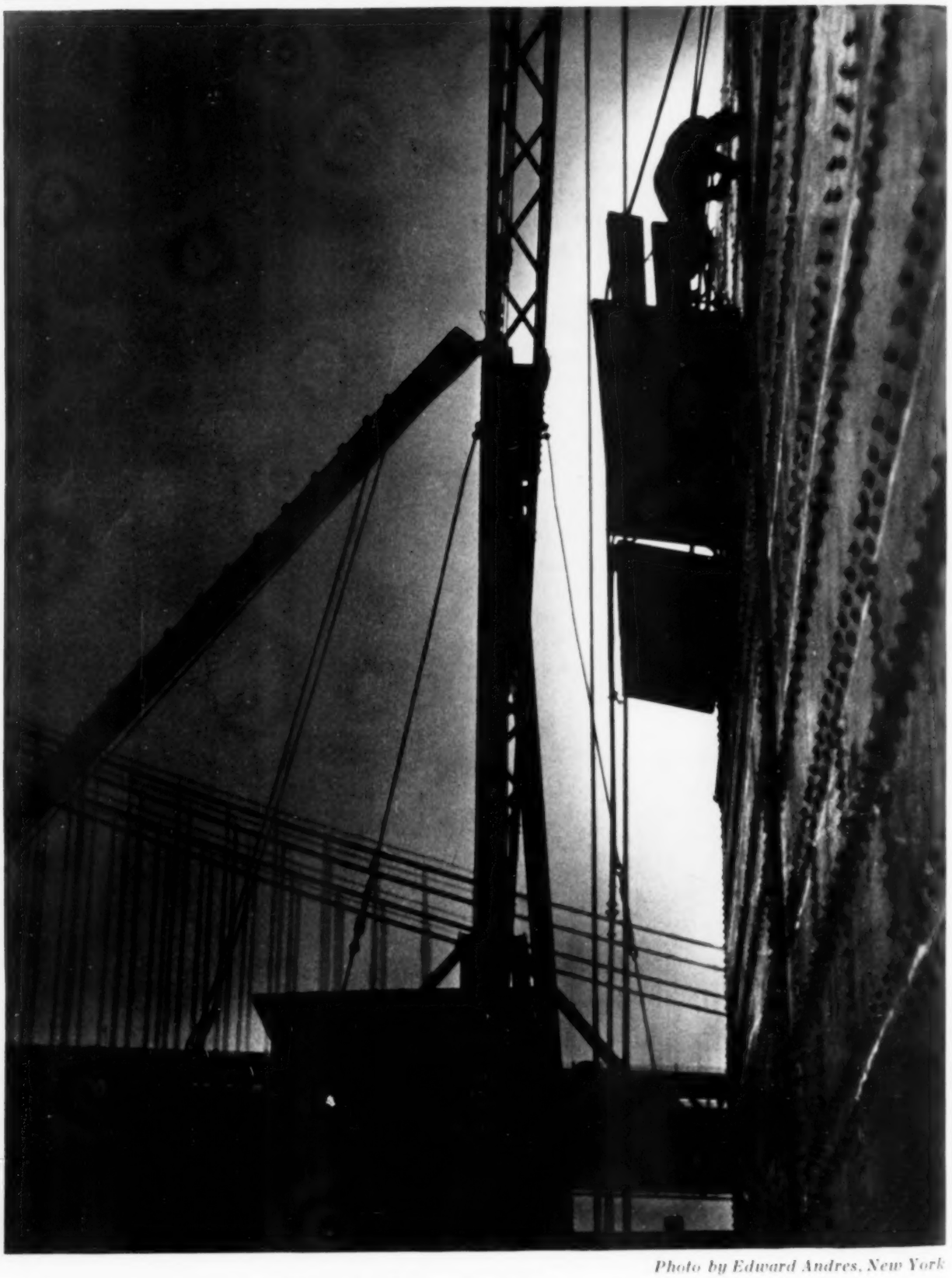


Photo by Edward Andres, New York

Steel Construction

Editorial

More on the Practicability of Dirigibles

PROPONENTS of the large dirigible have criticized the May editorial "In Memory of the Akron" on the basis that it presented only one view and also that it erroneously inferred from early stories of the survivors that the ship broke in the air, whereas Lieut-Commander Wiley's final testimony before the Board of Inquiry makes it appear probable that she withstood the violent buffeting until she was blown, tail down at a steep angle, into the water.

Therefore the following is given, in an effort to summarize the attitude of those who still believe this type of flying ship is useful and practicable:

The log of the rescue ship, the Phoebus, notes that a "wind force 10" (a full gale 60 to 70 miles per hr.) was blowing at the time of the disaster. If the Akron did not suffer major structural damage while she remained in the air, it is a fair conclusion that her strength was sufficient to meet even this particularly violent storm.

Much evidence was presented as to the staunchness of the ship, both in its final flight and during previous encounters with stormy weather. Such doubts as are expressed are not as to the design and construction of the craft, but as to the wisdom of scheduling a flight when adverse weather conditions were reported within the area to be traversed.

It is easy to be wise after the event, and point out that the course was direct into the storm, but suddenly the Akron, which had so far been flying in air conditions of remarkable uniformity, entered a region described by Wiley as "exceedingly turbulent atmosphere." No direct evidence is available as to the cause of the ship's final plunge, other than strong vertical wind currents. The Akron was equipped with very positive means for checking a loss of altitude, but some of these are of an emergency nature and the Captain might hesitate to use them unless he had positive evidence that a crash was imminent.

The future task of designers must therefore be to develop more precise auxiliary navigational equipment which will reflect continuously the altitude of both ends of the ship, the nature of the wind forces acting on the structure, the ship's "condition of heaviness," and her true path and rate of motion along this path. Constant wireless communication with meteorological stations, despite lightning storms and static, is also essential.

With positive information of this kind, the captain would be fully warned of impending difficulty, and could choose his course and flight altitude so as to avoid difficulty.

Metal Kegs for Beer

DOUBTLESS most of the beer drinkers, either of pre-prohibition or of quite recent persuasion, are unaware of the fact that the common wooden beer keg is lined with pitch, think of it! *pitch!* "Aged in the wood" means something to whiskey but nothing to the less fiery liquid, for even brief contact with seasoned oak introduces a tainting taste. Hence the keg gets an internal swabbing with pitch, which may at intervals be burned out and easily renewed.

This very lining of pitch enables the steel industry to stage a vigorous drive for new business in beer kegs. If pitch will protect beer from wood, why would it not also protect common steel from beer? The answer is that it will; but imagine the task of selling the idea to a beverage-industry that knew nothing about pitch-lined containers!

Stainless steel and aluminum have many important advantages over wood for barrels, but also have the one overpowering disadvantage

of high price. What is needed is something that costs no more than a keg — and this the sheet steel industry can offer in plain carbon steel, pressed to shape and welded at the joints. The principal production problem is to make the lining stick to smooth metal; this has been solved by A. O. Smith Corp. with a special pitch having strong adherence, and by Murray Body Corp. with a roughened or porous metal surface.

Either of these concerns, having a wealth of experience in handling and welding sheet and thin plate, has long ago solved any manufacturing problems which might arise in the fabrication of tight drums. To hold business in the automotive industry, it has been necessary for them to modernize their equipment and methods continually. They surely are far in advance of representative cooperage shops in this respect. Likewise it is easy for them to get any quantity of metal, but properly seasoned wood cannot be had overnight. It would appear that their competitive position is excellent.

It should be easy to demonstrate to brewmasters that the steel barrel is interchangeable with the old-fashioned wooden keg. They are not merely just as good, they are better — lighter and sturdier. They may easily be cleaned and sterilized. They can be made the same shape and size as the wooden barrel, so they will handle and stack in the customary way, and take their place on existing conveyors and filling equipment without any trouble whatever. To the common objection that a metal barrel in the sun will absorb so much heat as to endanger its contents, the steel industry offers a double-walled barrel (a "thermos" barrel) at a competitive price and considerably lighter than a wooden one.

It would appear that the principal thing to look out for is the outside appearance. A beer keg is washed at both ends of the trip, and stored in damp places. Bare steel rusts badly under such circumstances. Steel barrels may be painted, plated, slushed or chemically treated, but beer kegs are handled none too gently, and such protective coats will not last very long. Yet it is certain that customers will not like to handle rusty kegs, nor will drinkers particularly relish the contents of such an unprepossessing container.

When the continual maintenance of paint on exterior and pitch on interior is taken into account, perhaps the most economical barrel after all (despite the high first cost) will be a stainless, "clad," aluminum or alloy barrel. Introduction of such expensive materials will be slow, as long as the brewing industry is so short of ready money, but there is one feature that will be looked into carefully by the progressive concerns: A small container ("keglet") for home delivery in place of a case of bottles. Domestic trade will demand attractive containers, and might readily pay enough to warrant the bright, corrosion proof alloys now available.

Laugh of the Month

IN A spreading newspaper advertisement of the company that promotes "fresh gasoline" appears a photograph of an elderly gentleman patronizingly smiling at a pair of innocents (male and female) and waving his hand at a sagging spring on a screen door. "See that spring," says the chemical engineer. "It had plenty of strength when it was new. But now look at it. *Something* has gone out of it. Age also harms gas. . . ."

That's bad enough, but chalk up one stroke to the credit of that same ad: The artist didn't dress the chemical engineer in surgeons' togs. If the account executives (as they are called in the best advertising circles) have learned to distinguish between the attire of these two professions, perhaps eventually they'll get around to having their technical allusions checked up by a technologist.

News from the Soviet

READERS of the Foreign Correspondence, month by month, have found only two or three contributions from U.S.S.R. This has not been because of any lack of interesting things going on over there, and attempts on our part to discover a regular correspondent to tell about them. What appears to be a satisfactory arrangement has now been made with B. M. Suslov, an English-writing metallurgical engineer at present attached to the research department of the "Trust Grosneft." His second letter appears on page 47.

By H. Bornstein
Deere & Co.
Moline, Ill.

HIGH STRENGTH IRON

control of alloying elements

LAST month, in the article, "Cast Iron as an Engineering Material," an attempt was made to present the principal characteristics of gray cast iron which recommend it to designers of machinery. The present article will discuss the specific influence of the common alloying elements and the commercial production of high test iron, so-called. The third in the series will appraise briefly the role of heat treatment in improving the physical properties.

The elements ordinarily found in cast iron have been extensively studied and information about them is so widely held that the situation may be summarized thus:

Carbon is the most important element, and the effect of the others is largely the effect which they have on the carbon. Carbon in gray iron occurs in two forms: (1) Free carbon or graphite and (2) chemically combined carbon or iron carbide. If the casting analyzes very low in combined carbon the matrix is largely ferrite (as it would be in steel). With about 0.6 to 0.7% combined carbon, the matrix is nearly all pearlite. As in steel, with other factors equal, the strength and hardness increase with increase in combined carbon or pearlite.

The metallic matrix of gray iron is filled with thousands of curved flakes of graphitic carbon. These flakes are soft and weak and are responsible for the lack of ductility in cast iron and the ease with which it can be machined. Graphite flakes have an effect on the strength of cast iron according to (1) size, (2) shape, (3) distribution, and (4) amount, and these facts are the basis of many of the high strength irons to be discussed later.

Phosphorus combines with the iron to form iron phosphide (Fe_3P) which dissolves in the iron. Phosphorus has an embrittling effect on the iron which materially reduces the deflection values in the transverse test.

Manganese in gray iron has two forms—manganese carbide, which is associated with iron carbide and pearlite, and manganese sulphide, which occurs as small slate-colored inclusions throughout the metal. In the ordinary commercial ranges, it has little effect on mechanical properties.

Sulphur occurs largely as manganese sulphide and infrequently as iron sulphide. Under proper operating conditions the sulphur does not seem to exert harmful effects on gray iron in amounts up to as high as 0.15%, provided there is sufficient manganese present.

Silicon is in solid solution in the ferrite and is not observable under the microscope. It pro-

motes and assists the decomposition of the combined carbon into graphite. In changing white iron to gray, through graphitization, silicon makes the commercial production of gray iron practicable. For strong irons, just sufficient silicon should be used to insure decomposition of all the free iron carbide (massive cementite), but the decomposition of pearlite into graphite and ferrite gives a weaker and softer metal.

Alloying Metals

Nickel is usually added to gray cast iron in amounts from 0.25% to 5.0% for general engineering applications, often in combination with other alloying elements. Nickel influences machinability, texture, hardness, density, and heat and corrosion resistance.

Nickel acts as a graphitizer and does not form a carbide. In small amounts, it reduces chill and softens the iron by suppressing free carbide (which is hard) and thus promotes machinability. Larger amounts harden iron by forming a matrix of sorbite and martensite, rather than pearlite. The range of hardness wherein gray iron is machinable is increased by the addition of nickel.

Nickel promotes density and freedom from porosity by permitting the use of a low silicon iron for light sections without danger of getting chill or hard spots. Nickel up to 4% in iron of suitable base composition promotes uniformity of grain, hardness, and strength throughout sections of considerable thickness or in castings having uneven sections.

As the amount of nickel is increased from 10 to 18% there is a gradual change in structure to non-magnetic gamma iron with corresponding important changes in properties. Austenitic gray irons such as "Ni-resist" (nickel 14, copper 5.5, chromium 3 to 6, silicon 2, and carbon 3%) are practically free from growth and are non-scaling at temperatures up to 1500° F. They are much superior to non-austenitic irons for resisting action of various acids, alkalis, salts and other corrosive agents.

Chromium is essentially a carbide-former, in contradistinction to the graphite-forming elements such as silicon and nickel. In sufficient amount it increases the combined carbon and tendency to chill — that is, chromium-iron double carbides are more stable than straight iron carbides and graphitize less readily.

Chromium reduces the graphitic carbon

Comparative Cast Irons Without and With 0.25% Molybdenum. Both have 3.15% total carbon and 2.45% silicon. 500 magnifications

content and decreases the flake size, and favors the formation of more finely laminated and harder pearlite. For suitable base irons these effects add to tensile strength, promote finer grain size, and increase hardness. Above a certain maximum (usually about 1% chromium in soft iron and with medium section) free carbides appear which hinder any machining operation. Unless graphitizing alloys such as nickel are added, 3% chromium irons have entirely white fractures — that is, graphitization is totally prevented. Higher percentages of chromium may be added to produce special purpose white irons where freedom from scaling, toughness, or chill are desired.

The carbide stability conferred by chromium is useful in the heat treatment of gray cast iron, inasmuch as excessive graphitization does not offset the advantages conferred by structural changes within the matrix. It also increases the tensile strength at elevated temperatures and minimizes tendency toward growth.

Molybdenum enters into complex carbides and also into ferrite solid solution. As a carbide former, it is much less drastic in action than chromium. As shown in the comparative micros opposite it causes the graphite flakes to be somewhat less extensive in form with a consequent improvement in physical properties of the iron. (The writer would like to acknowledge help from R. S. MacPherran of Allis-Chalmers Mfg. Co. in the illustrations.)

Molybdenum is very valuable and perhaps the most effective element added to gray cast iron to increase strength and toughness. The pearlitic structure approaches the sorbitic if sufficient molybdenum is added. It also retards the critical transformation, making the volume changes less drastic and the rate of graphitization slower. Such effects help in heat treating processes and also in the retention of strength at elevated temperatures. Molybdenum is also valuable in increasing the resistance to growth of cast iron.

Vanadium is added to cast iron in amounts varying from about 0.1% to about 0.5%. The following effects are observed: (1) Interference with graphitization, that is, stabilization of cementite; (2) smaller graphite flakes and more uniform graphite distribution under given casting and cooling conditions; (3) tendency to retain the sorbitic structure; (4) decrease of grain size of matrix. These are obviously the effect largely of carbide stabilization.

Titanium has a graphitizing influence on cast iron like silicon but stronger than that element in small amounts. This involves, of course, an increase in ferrite formation and a decrease in the chilling tendency when titanium is added. Oxidizing and scavenging effects of titanium on cast iron have been reported.

High Strength Iron

Tremendous progress has been made in the United States in the past half dozen years in the production of high strength cast iron. Up to about six years ago 35,000 lb. per sq.in. was considered high and, until the adoption of the tentative specification by the American Society for Testing Materials last June, the standard high strength iron called for a minimum tensile strength of 33,000 lb. per sq.in. Today there are many foundries that are regularly producing cast irons with tensile strengths upwards of 50,000 lb. per sq.in.

Many methods are used. In general, it may be said that the higher strength irons are produced through low total carbon content (3% and less). They may be made by various melting processes such as the cupola, air furnace, electric furnace, rotary furnace of the Brackelsburg type, and certain combination processes.

In the cupola process, a high percentage of steel is usually used in the mix and a portion of the silicon is added to the ladle. Frequently, nickel is also added in order to improve the machinability, and other alloys such as chromium or molybdenum are sometimes added.

High Strength Irons From Cupola

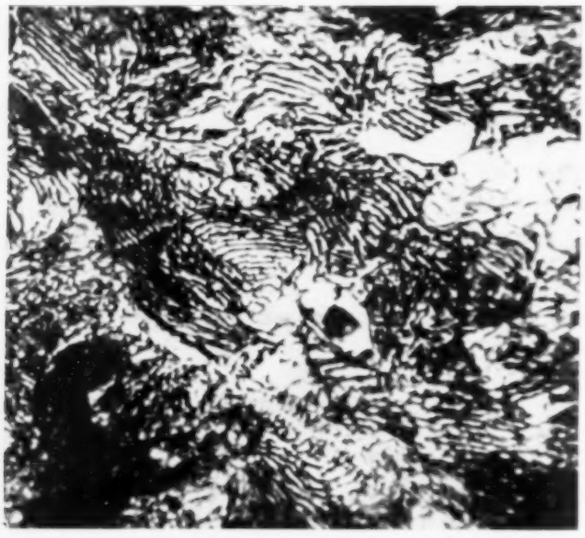
	A	B
Analysis		
Total Carbon	2.64%	2.64%
Silicon	2.14	2.16
Sulphur	0.08	0.084
Phosphorus	0.08	0.08
Manganese	0.69	0.73
Nickel	1.12	None
Chromium	0.08	0.08
Molybdenum	None	0.34
Tensile Strength	73,000	70,000
Brinell Hardness	285	277

Some very practical suggestions as to methods of manufacture were made by F. B. Coyle in METAL PROGRESS, February, 1931. Representative analyses and properties are given in the table at the foot of page 39.

The air furnace is used to produce high strength cast irons and a typical air furnace iron giving minimum tensile strengths of 50,000 lb. per sq.in. is as follows:

Total carbon	2.75 to 3.00%
Combined carbon	0.65 to 0.75
Silicon	1.80 to 2.20
Manganese	0.40 to 0.60
Phosphorus	0.16 to 0.18
Sulphur	0.08 max.

This method gives a Brinell hardness of 190 to 220 on the test bar. The structure is fully pearlitic, similar to high strength cupola iron.



Semi-Malleable Iron; Carbon 2.34%, Double Treated to Tensile Strength Over 100,000 Lb. per Sq.In. A little graphite, a little ferrite, mostly laminated pearlite. 2000 magnifications

The machining speed is from 90 to 135 ft. per min. with stellite and about 300 ft. per min. with tungsten carbide.

The adjoining table gives the analysis, strength, and hardness of typical high strength irons made in the electric furnace. *A* is a nickel-chromium-molybdenum iron used for automotive castings. The iron *B* has molybdenum as the sole alloying element. The last has medium strength without alloys and fairly high carbon.

Electric Furnace Irons

	A	B	C
Analysis			
Total Carbon	3.02%	3.17%	3.24%
Silicon	2.36	2.47	2.47
Sulphur	0.086	0.061	0.071
Phosphorus	0.13	0.154	0.16
Manganese	0.82	0.90	0.90
Nickel	0.44	–	–
Chromium	0.37	–	–
Molybdenum	0.58	0.26	–
Tensile Strength	54,000	50,000	40,000
Brinell Hardness	241	228	192

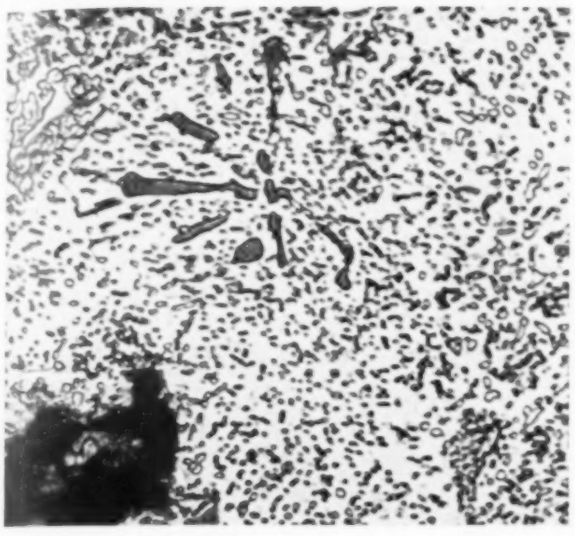
Duplex melting for high quality castings is frequently employed. The metal is melted in the cupola and then refined and superheated in the electric furnace or air furnace. The combination is used because, for high production, the combined melting cost is lower than melting cold metal in the electric furnace or air furnace.

Special Cast Irons

Mechanite is the trade name applied to cast irons where the molten metal has been treated with calcium silicide (a patented process). The metal may be melted in the air furnace, cupola, or electric furnace. A large proportion of scrap is usually employed, and the composition is adjusted so as to produce a metal which would be a white iron in case the calcium silicide were not added. The latter acts as a graphitizer and also produces a fine graphite structure. Resulting properties are described by Oliver Smalley in METAL PROGRESS, May, 1932.

Promal is a patented heat treated malleable iron. The annealed malleable iron is heated at about 1450° F. for a definite period of time (depending upon the section of casting) and then oil quenched and drawn. This treatment increases the combined carbon from practically zero to about 0.35%, with a resulting increase in Brinell hardness and strength, and a small loss in ductility. Wear resistance is much improved.

Zeron Metal is another patented product and a modification of malleable cast iron. The regular malleable white iron analysis is used except that the manganese is higher, ranging from 0.80 to 1.00%. Annealing is carefully controlled according to the following schedule so as to leave a definite amount of spheroidized



Zeron Metal; Spheroidized Cementite in a White Iron, Heat Treated by Complex Process to 75,000 Lb. per Sq.In., 15% Elongation and 175 Brinell. 1000 diameters

cementite in the casting, resulting in higher tensile strength and greater hardness: Heat at 1700° F. and hold 20 hr., cool to about 1100° F., reheat to 1400° F., cool to 1000° F., reheat to 1280° F. and hold for 25 hr., and cool in air. Physical properties are then as follows:

Tensile strength	70,000 to 80,000
Yield point	55,000 to 60,000
Elongation	14 to 16%
Brinell hardness	170 to 180

Semi-Malleable Cast Irons — There are a number of these made today. A white iron is first produced and this is given a special heat treatment which partially graphitizes the carbon. Such a structure is shown on page 40. This iron has a carbon content of 2.34% and silicon 1.37%. It was held at 1700° F. for 8 hr., air quenched, reheated to 1200° F. for 15 min., and oil quenched. This gave a tensile strength of 107,000 lb. and 2.5% elongation in 2 in.

Ford Motor Co. has developed a special heat treated iron which it has patented, claiming that this metal has the desirable properties of both malleable cast iron and gray cast iron. An iron of about 3.5% total carbon and 2.7% silicon is poured into a metal mold. The quick cooling suppresses large graphite flakes. The casting is then heated to 1600 to 1700° F. for 1 to 3 hr. and this gives a metal with Brinell hardness of 228, and the carbon collected in small rounded particles, a structure analogous to malleable iron. After machining, the casting is heated to 1550° F. to 1600° F., held 10 min., and oil quenched. It is then tempered. According to the patent specification the carbon is then more finely distributed in small nodules, and the matrix a mixture of martensite, troostite and sorbite. Articles such as camshafts and push rods are made by this process.

Brake Drums — Cast iron brake drums are a recent development now being used largely in the automotive industry. Many types of iron are being used: One prominent manufacturer is using a molybdenum electric furnace iron of high strength; another foundry is producing an air furnace iron without alloy addition, while still another is supplying an air furnace iron with about 1% nickel.

For bus service another foundry supplies a cupola iron having a tensile strength of 35,000 to 40,000 lb. per sq.in. with the following typical analysis: Total carbon 3.30%, silicon 2.00, sulphur 0.08, phosphorus 0.20, manganese 0.60, nickel 1.20, and chromium 0.60. This iron has a pearlitic structure with some free cementite, and it is claimed that this free cementite has proven beneficial in service. *(Cont. on page 60)*

High Alloy Iron; a Brake Drum Containing 24% Chromium Heat Treated to Brinell 325 and 85,500 Lb. per Sq.In. 250 magnifications

Correspondence and foreign letters

Steel Buildings of a New Type

TURIN, *Italy* — The relatively high cost of structural steel prevailing in Italy, compared with other building materials, has been a great handicap to the development of steel frame buildings in this country. During the last 30 years the requirements of modern architecture have therefore been met preferably by reinforced concrete.

But in the last few years, the substantial reduction of steel prices having removed the main obstacle, Italian architects have given more and more attention to this type, and many large buildings have been erected with steel skeletons or are now under construction.

The new fusion welding processes — now so largely used here for all types of steel construction and especially in shipbuilding — have been applied with great success. Many large steel office buildings, especially in northern Italy, have been entirely welded.

One of the firms which has worked with much success in this field is the Società Nazionale delle Officine di Savigliano of Turin. It is now developing an entirely new type of steel building, invented by the architect Guido Fiorini. This new system is named *tensistruttura* (which could be approximately translated "tension structure") and consists of a special static arrangement of tension members to balance the total weight of the structure about one or more central piers, whose type and special dimensions are particularly designed to withstand the compression stresses. The advantages claimed are as follows:

1. More than two-thirds of the members of the structure can readily be reduced to a few simple standard units. With the exception of the central portion, which is loaded with stresses increasing from the top to the base, all the rest of the building is free from the weight of the upper floors, so that the frames of all the floors are identical.

2. Due to the generous use of tension rods for main members, much weight of metal is saved, since a long tension member carrying a certain load may be made much lighter than a strut or column for the same duty, because the latter must be stiffened against buckling. Though exact comparisons of a general character are very difficult to make, it may be stated that in a number of specific designs the weight of steel per cubic foot for buildings of the new system is only about 70% of the weight of steel used under identical conditions for conventional steel skeletons.

3. Since the building is practically suspended around a central structure, only that central portion rests on the ground. There are no outside posts. This leaves great spaces free for display rooms or concourses on the most valuable portion of the site, or it readily allows of wide arcades for traffic at the street level. For instance, a building covering 1100 sq.m. has an area of the central structure resting on foundations of only 750 sq.m.

4. The reduction of the number of foundations means a great reduction in their total cost. This economy may reach 50%.

The French architects Le Corbusier and Jeanneret have adopted this type of building in their scheme for the construction of a new section of the city of Algiers. Aside from a purely architectural point of view, which appeals strongly to the present-day school, this new system of construction has many interesting possibilities to metal makers and builders. Particularly it appears to upset the former division of field between steel skeletons and reinforced concrete frames.

FEDERICO GIOLITTI

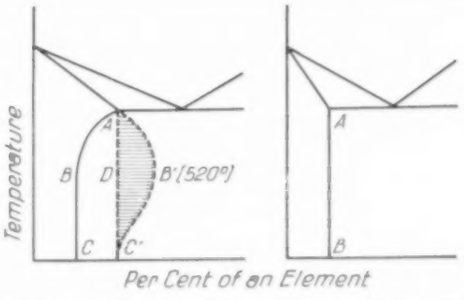
More Light on Temper Brittleness

SENDAI, *Japan*—A quenched carbon steel is very hard and brittle, but if it is tempered at a high temperature and cooled slowly, it acquires a certain degree of toughness. The toughness of some special steels, however, in the tempered and slowly cooled state is less than when tempered and quenched. This abnormal action is called temper brittleness, and is usually explained by the presence of carbides. Quite recently Saburo Watanabe and Kiyoshi Nagasawa further developed this theory and were able to explain many particulars concerning the phenomenon.

At first they studied, statistically, tests on a large number of different steels and arrived at the result that temper brittleness depends on the nature of the elements added to steels — that is, on whether or not they are more soluble in ferrite with rising temperature. Thus, the elements chromium, manganese, silicon, nickel, and phosphorus certainly promote temper brittleness, while sulphur, molybdenum, and tungsten do not. The solubility of an element in the first-mentioned group should increase with temperature, as is shown by line *CBA* of the left diagram, and that of the others should remain constant as is shown by *BA* in the right-hand diagram.

A closer investigation reveals the fact that there are two kinds of temper brittleness: One makes itself evident after reheating within the range 450 to 520° C. (850 to 970° F.) and is not affected by the rate of the final cooling; the other variety occurs after heating above 520° C. and it makes a large difference in toughness whether the specimen is quenched from the tempering temperature or slowly cooled. This second variety has hitherto been known as "temper brittleness." To distinguish these two kinds Watanabe and Nagasawa have called them "first temper brittleness" and "second temper brittleness."

To aid in the explanation of the experimental and practical facts it should be remembered that when martensite of an alloy steel (a supersaturated solid solution of a carbide) is tempered at different increasing temperatures, precipitation of the carbide takes place at a gradually increasing rate. Let us suppose the horizontal width of the shaded area in the left-hand diagram to represent the amount of the precipitated carbide at each corresponding temperature; then *C'B'* is the curve of precipitation, *DB'* being assumed to be the maximum amount of carbide possible. Above temperature *D* (520° C.) carbide again dissolves into ferrite, as shown by the solubility line *BA*, so that the amount of free carbide gradually diminishes with the rise of temperature and vanishes at the temperature *A*.



Structural Diagrams Representing Alloys Whose Solid Solubility Decreases With Decreasing Temperature (Left) and Systems Where Solid Solubility Is Substantially Independent of Temperature

Now if quenched steel is tempered somewhere below the temperature *D*, the amount of carbide precipitated increases with the temperature (at first slowly and then rapidly) until *D* is reached; the amount existing after a given low heat treatment remains, however, unchanged by subsequent slow or rapid cooling. On one hand, precipitation of carbide increases the toughness of the martensite; presence of hard

carbide within grains or on grain boundaries decreases, on the other hand, the toughness of the specimen. Hence a curve plotting impact value against tempering temperature would rise slightly and be concave downward, as seen from the left-hand portion of the curves in the diagrams at the bottom of this page.

This is the "first temper brittleness" and must be independent of the rate of cooling from the tempering temperature.

By tempering at a temperature higher than *D* (520° C.) the free carbide produced during reheating up to 520° is absorbed more and more in ferrite as the temperature rises above that figure. But during a slow cooling to room temperature, this absorbed carbide is again set free, and the amount which is present in the cold sample is the same as though the quenched metal had merely been reheated to 520° C. On the other hand, if the specimen is quenched from the high tempering temperature, the absorbed carbide remains as such. Hence specimens slowly cooled after tempering from above 520° C. contain a greater amount of free carbide and therefore have a smaller impact value than specimens quenched after the same tempering; this difference between the impact values increases with the rise of temperature up to the point where carbide has the maximum solubility in the steel.

This is the "second temper brittleness" and is usually known simply as "temper brittleness."

From the above view, not only a quenched but also an annealed steel should show the "second temper brittleness," provided the solid solubility line is as shown in the left-hand diagram. An actual test on a steel containing 0.35% C, 1.05% Cr, and 3.44% Ni confirms this conclusion.

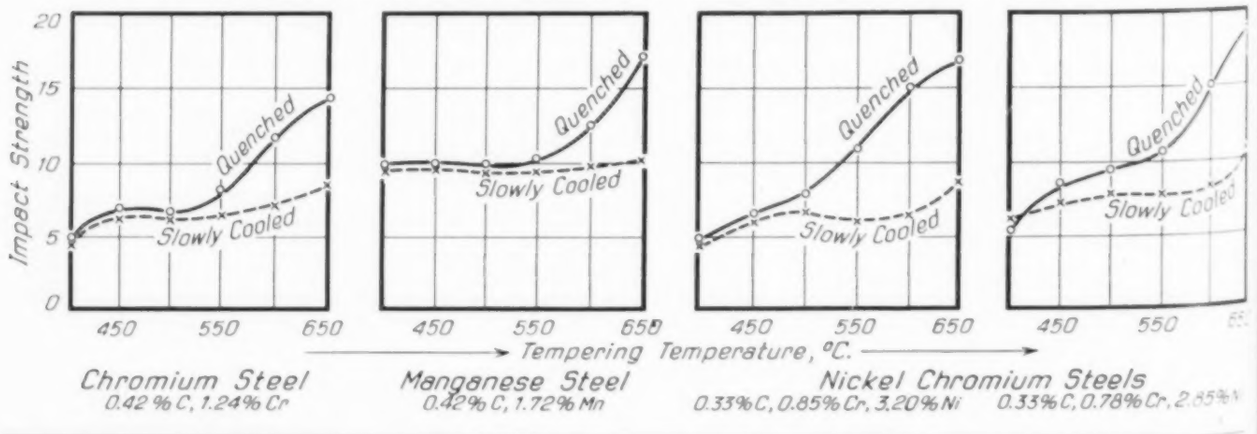
It is a well-known fact that molybdenum of only 0.5% prevents the second temper brittleness in nickel-chromium steel; this is explained by the effect of molybdenum in changing the solubility curve from the form *ABC* to a straight vertical line *AB*.

KOTARO HONDA

Measuring Smoothness by Optics

PARIS, *France* — Determination of the exact geometrical condition of a metallic surface is quite important for many investigations (and if simple methods could be devised they would doubtless find ready industrial use). Among these may be mentioned the study of machinability, excellence of polish, and the efficiency of sundry abrasives. Precise studies of corrosion, chemical protection, or electroplating all require an accurate estimate of the initial and final condition of the surface. Condition

Curves Showing Relation of Impact Strength of Quenched and Tempered Alloy Steels, as It Varies With Tempering Temperature and Speed of Cooling Afterward



of the surface also affects problems of friction, lubrication, high-frequency noises, impact and fatigue.

To define this geometrical state, one may usually have recourse to the following means:

1. Direct metallographic study of the surface by changing the focus or the nature, intensity, and incidence of the illumination.

2. Examination of gelatine molds reproducing the surface in detail, by methods described by W. N. Thomas, *Engineering*. (London) Oct. 12, 1932.

3. The same result may sometimes be obtained by magnifying the movements of a fine point resting on the surface (Firestone, Durbin, and Abbott, METAL PROGRESS, April, 1932).

It is also possible to have recourse to sound waves. Thus, R. E. W. Harrison makes the surface move like a phonograph record under the sapphire point of a pick-up connected to an amplifying system. The pitch and the regularity of the sound and the electrical currents involved are then observed.

The above procedures can hardly be adapted to rapid control methods. For that purpose the present writer some years ago proposed to measure the reflective power by suitable photometers. The photo-electric cell now gives an accurate means of measuring the intensity of incident and reflected beams, independent of the personal equation.

In order to be specific, two examples connected with the study of corrosion may be cited as applications of the above principles.

A. An estimate of the degree of polish in a sample prior to corrosion: When the polishing is rectilinear, the reflected light depends on the angle of incidence α (that is, the angle formed by the luminous ray and the surface) and on its azimuth w (that is, the angle of the incident plane with the direction of the polishing). Reflection is at its maximum when $\alpha = 45^\circ$ and $w = 90^\circ$. If the amount of reflected light is plotted as a function of α, it has the shape of a bell, and the maximum is more pronounced and greater as w approaches 90° and as the polishing abrasive is finer and finer.

The result is that "perfect" polishing, which resists corrosion so well, is not defined exactly by such a method, since the least variation of incidence has an influence on the intensity of the reflected light, and it is true that a rigorously plane surface is not easily obtained over a large area. On the other hand, reflection from a rough polish (favorable to corrosion) depends more upon the azimuth w of the beam, which must be accurately controlled. Sand blasted surfaces are more easily measured, since the amount of reflected light is then independent of the azimuth.

B. Estimate of the result of corrosion: Corrosion manifests itself by a decrease of the reflective power, which in turn is a function of the intensity and of the type of corrosion, as I pointed out in METAL PROGRESS last July, but the usefulness of measuring the reflectivity of a corroded surface is limited, since it is not very sensitive if the corrosion is intergranular; furthermore, the reflective power after general corrosion is sometimes modified very little.

When corrosion is of the pitting or penetrating type, the curve representing the variation of the reflective power as a function of the etching time has an exponential or parabolic form, since such corrosion multiplies and deepens the pits and widens the craters.

If etching colors the surface, measurements must be made in monochromatic light, and the intensity of the reflected light must be determined through monochromatic filters. Experience has proved that radiations of single wave lengths are sufficient to define, in practice, a complex color.

In conclusion, it may be said that these colorations are due to the formation of thin films. If the refractive index of the film is known, its thickness may be calculated by the interference effects set up on the light waves. The best known example is tempering colors. Analyses of these colors produced on various steels show very clearly the differences between the oxidation speeds at working temperatures. We shall give later some examples and applications of the classification of the color of metals and alloys.

ALBERT PORTEVIN

Foreign Letters

Water-on-Oil for "Graded Hardening"

MAGDEBURG, *Germany* — At the Leipzig fair some products were exhibited which were new to the steel treating fraternity in our country. One most interesting thing was a sectional tank, fitted with a plate glass front, so that visitors could witness the quenching of hot steel into various mediums. Of the latter, some quite remarkable results were secured in a combined oil and water bath; this oil was refined by the German Houghton Co. in such a way that all saponifiable matter had been extracted, so that even if the oil and water were stirred very vigorously, the oil would settle to the bottom immediately.

It has been found that carbon and low alloy steels hardened first in the water layer for a definite time and then dropped into the oil below showed a greater Rockwell hardness than had been obtainable even with cold water alone, and a much stronger structure and higher toughness besides.

The following figures are surprising but have been verified by several series of independent tests.

Rockwell C Hardness After Various Quenches at 45°F.

	0.9% Carbon	VCN-15	Tungsten
Water	64	53.5	66
Light Oil	44	50	45
Water 2 Sec., Heavy Oil	41	50.5	66
Water 4 Sec., Heavy Oil	58.5	55	68.5
Water 6 Sec., Heavy Oil	63	56.5	69.5
Water 8 Sec., Heavy Oil	66.5	58.5	69
Water 10 Sec., Heavy Oil	65	57	68.8

Steel VCN-15 is similar to S.A.E. 3125. The tungsten steel had about 1.5% carbon and 5.5% tungsten — an analysis used for the rifling of guns. It usually is very brittle after a water quench; in these tests the samples would ordinarily break in the water bath. Pieces quenched 10 sec. in water and then cooled in the heavy oil underneath frequently broke spontaneously shortly after withdrawing from the bath, but strangely enough the pieces 6 sec. in water are so tough that an attempt to break them on an anvil failed.

Another byproduct of quenching in "oil heavier than water" is the discovery that in many cases a drawing of the temper is unnecessary. Through the slow cooling in oil after a graded water quench, all internal strains seem to be relieved and the pieces become so fine-grained and tough that no further treatment is required. The original high hardness obtained through the water quenching thus can be retained without risk of cracks.

This new hardening method seems to open great possibilities for the hardening of all steels except oil and air hardening high alloy steels. Results obtained are in general agreement with the theory of "graded hardening" as set forth by Dr. Diergarten in METAL PROGRESS for March. By using a combination quenching bath (heavy oil underneath clear water) a practical means is provided for quenching a small piece quickly to a certain temperature — governed by the time of immersion — and then cooling slowly so that the retained austenite can transform directly into a tough structure of ferrite and cementite.

R. KIMBARA

Wisdom Ribbon

MONTREAL, *Canada* (McGill University) — May I offer a small correction for the April issue of METAL PROGRESS? In Giolitti's Italian letter, p. 47, he refers to the "wisdom ribbon." This should have a capital "W," as it is named after its inventor, Stuart A. Wisdom, of the staff of Shawinigan Chemicals, Ltd., Quebec, and a graduate of McGill University.

For readers who are not familiar with this, a few words of description might be in place. The ribbon consists of a coil of strip steel like a glorified tape measure. A number of these are suitably supported in the steelwork above the furnace. The free end is welded to the sheath of the Söderberg

electrode and the escapement is controlled by suitable brakes or ratchets. The strip unwinds as the electrode descends, and from time to time new coils are attached to the sheath; this gives very good and safe control of the lowering of the electrode as it is consumed.

GORDON SPROULE

Ferrovanadium From 0.1% Ore

GROSNY, *U.S.S.R.* — As is well known, a number of wholly new industries have been created in the Soviet Union since 1924, among them the manufacture of machine tools, tractors, automobiles, and chemical apparatus. These demand much high grade steel, of which vanadium is an essential constituent, and an effort has therefore been made to establish a ferrovanadium industry in the U.S.S.R.

A sufficient amount of vanadium compounds to supply our needs as catalysts in the production of sulphuric acid and other chemicals has been produced since 1931 in the Rare Metal Works in Moscow. This is purely a by-product of the refining of radium ore mined in the Ferghana field in Turkestan. While the chemical methods used are of great interest, and are a matter of considerable pride to us since they were developed by Soviet specialists, they do not promise to be of use in the production of ferrovanadium, since the supply of this ore is very limited.

Geological surveys have so far failed to locate any ore bodies containing sizable percentages of vanadium. The best prospects for success seemed to be the treatment of one of several iron ore deposits, and a semi-commercial plant is now in operation at the Kerch Steel Works (which makes basic bessemer steel rails and structural shapes, and is located in Crimea near the Black Sea). This plant operates on a large deposit of hydrated phosphoric iron ore containing from 0.11 to 0.17% V_2O_5. Successful extraction of such small amounts of vanadium from the above-mentioned ore has represented a most difficult problem; it probably is done nowhere else in the world.

In regular smelting this ore is first dried and sintered by Dwight-Lloyd machines, and the clinker (containing about 0.10% vanadium) reduced into pig iron for basic converters. The iron analyzes 0.11 to 0.14% V, and nine-tenths of it eventually finds itself in the phosphoric slag (used as fertilizer).

For the purpose of extracting the vanadium, a ladle of the pig iron is oxidized with about 2.5% its weight of low phosphorus iron ore. Some of the silicon, manganese, and about one-third of the vanadium oxidize and pass into a very liquid slag, which is about equal in weight to that of the ore used; however, it analyzes 10 to 20 times as high in vanadium as the pig iron, which latter, of course, is then available for conversion into steel.

In order to extract the vanadium out of the ladle slag, the latter is treated chemically by the following method developed at the Institute of Rare Metals by Prof. M. Sobolev. The slag is mixed with 10% of common salt and finely ground, after which it is subjected to a chloridizing roasting in a reverberatory furnace at 1500° F. for 3 to 4 hr. About three-quarters of the vanadium is thus converted into a soluble sodium vanadate ($NaVO_3$) which is simply leached out with hot water.

Phosphates passing into solution are precipitated by magnesium salts, and filtered out. Solid lime (CaO) is next added to the hot clear solution and the mixture is agitated with live steam, and soluble $NaVO_3$ is converted into insoluble $Ca(VO_3)_2$ and settled out.

With the aid of an electric smelting process using ferrosilicon it is possible to obtain a standard 40% ferrovanadium from this calcium vanadate. Thus the total amount of vanadium which can be extracted out of the pig iron amounts to approximately 25% by weight of the vanadium contained in it.

The first experimental plant was manufactured in the Soviet Union under the supervision of our own specialists and is capable of processing 5 tons of slag daily. It is expected to raise its efficiency until it will produce 40 tons of vanadium a year, which is a large part of our present requirements.

B. M. SUSLOV

Foreign Letters

Gage for File Test

CHARLOTTENBURG, *Germany* — Your discussion of the file test for hardness has been of interest to us at the General Electric Co. plant, since we are convinced by much use that it is an excellent means of testing steel tools. Various other types of hardness testers have been highly developed, and one of them (Rockwell) generally favored for hardened tools, although too much faith is often placed in its dependability. It, like every other machine, needs careful attention and frequent calibration for precise work. Its two disadvantages are that the area tested is exceedingly small, and that the large pressure required will bend any projecting part, punch through sheets, or break thin, hardened cases. If the part has a uniformly hard and fine microstructure, and considerable mass, a Rockwell machine in good order is very satisfactory.

On the other hand, the file can test a considerable area and be placed directly at the spot which should be hard. Pressures are relatively slight and the effect of elastic movements in the piece tested can therefore be minimized. It also leaves the surface almost unmarked, and does not break through a nitrided case, for instance, thus testing the very surface rather than the metal underneath.

File testing has one well-known disadvantage — it depends upon the operator, his physical condition of fatigue and his general nervous sensitivity. Moreover, the files have not been standardized, and new ones from different manufacturers have different tooth forms and hardness. They also dull with use.

To compensate for these errors, it is possible to provide a series of balls or rings of increasing hardness, such as used by the file maker to control his production, and make frequent comparison with them. We have found that it is exceedingly difficult to harden and anneal to uniform surface condition a series of comparison pieces within the necessary tolerance. Furthermore, German file-makers' standard numbers have no logical relationship to the scale of any of our better-known hardness testers; one unit also corresponds to 1.5 to 2 Rockwell C units.

A much more handy and usable device has been patented by me and produced by Richard Weber & Co. of Berlin. It consists of a $\frac{3}{8}$-in. round bar of carbon tool steel about 4 in. long, mounted in a wooden handle. Along the length of the bar is ground a flat surface about $\frac{1}{4}$-in. wide. This bar is heat treated so that the Rockwell hardness is, say C-66 at the end and C-57 at the handle, the change being by insensible gradations. Hardness of each bar is explored by a single Rockwell tester in precise adjustment, and the scale of numbers etched on the flat surface at the proper place.

Testing procedure, using one of these gages, is as follows: Take the hilt of the file in the right hand and the gage in the left, and file ("touch") the gage on the spot marked with the desired hardness of the tool to be tested, using the flat of the file, not the edge. Then take the tool to be tested in the left hand and "touch" it with the file (same spot). The resistance to the touch must be the same. If it is not, try either to the right or left of the first spot on the gage for the area corresponding to the hardness of the piece, and read off the number directly.

Rockwell hardness numbers so determined are directly applicable if the tools are made of carbon steel, like the gage. With alloy steels a correction must be made according to experience with approved tools of such analyses. In all tests the proper procedure is to work within a tolerance, that is, the hardness of a given piece should be specified between two limits, say C-63 and C-64, and this area used on the gage bar.

Surfaces on the piece being tested and comparative surfaces on the gage should be of the same nature — that is, flat against flat, edge against edge, and round against round. Pieces of large diameter or large flats will seem considerably harder than pieces giving small contact with the file; this amounts generally to less than one unit, and should be allowed for by the specification engineer.

BERTOLD BUXBAUM, Dr-Ing.
Betriebsdirektor

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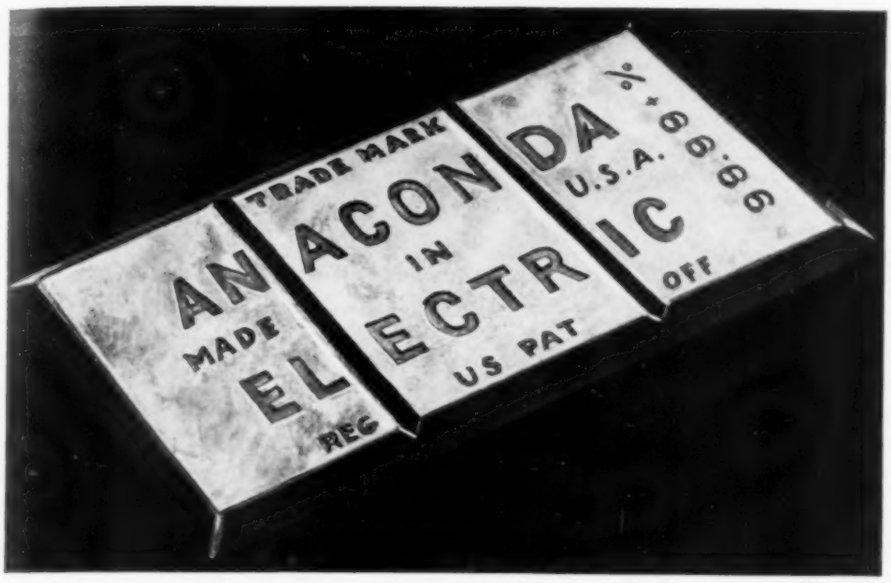
Concentrates from the literature

CONSTANT developments in very large blast furnaces have been necessary during the last five years, according to W. A. Haven ("American Blast Furnaces," British Iron & Steel Institute, May meeting). These large furnaces are exceptionally efficient when "slow blowing." When driven hard they require more heat in the blast, and to avoid building more stoves, the trend has been to reline old shells with multiple-hole checker tiles and use cleaner gas. Metal bottoms (cast iron columns and steel grids) are more satisfactory supports for checker work than masonry arches. Extra cleaning is generally done by wet scrubbing in towers, and is the most effective means of reducing metallic losses. The biggest item in reducing cost of pig iron has come from the beneficiation of ore, coke, and limestone. This includes screen sizing of coke and control of its physical characteristics. Much lake ore is now washed; most **BLAST FURNACES** sinter the flue dust. Mr. Haven thinks it will not be long before fine ore (say ¼ in.) will also be sintered, whereupon a single furnace can probably produce 1500 tons of pig iron daily. Outstanding economies have been attained through a more profitable use of the gas, as for heating coke-oven retorts and soaking pits, or mixed with other gases in open hearths and in various heating furnaces.

A RAPID method for dephosphorizing or deoxidizing steel invented by René Perrin, manager of the Electric Steel Co. of Ugine, was mentioned in METAL PROGRESS last February. As described in *Revue de Métallurgie*, Jan., 1933, it is based on the fact that the above two reactions between slag and steel interfaces are balanced reactions (in the physico-chemical sense), which may be accelerated if the area of contact surfaces be increased — other things being equal. Mr. Perrin's plan for **DEPHOSPHORIZATION** is to melt a very basic slag (3 to 10% SiO_2, 60 to 65% CaO, 20 to 35% FeO), thin it with fluorspar, place about 15 in. of it in a tall, narrow ladle, and dump 15 tons of steel into it from a considerable height. The violent shock sets up a great stirring action, and a metal-slag emulsion is formed which ascends through the steel and reaction is complete within 60 sec. Phosphorus analyses before and after are of this order: 0.44 to 0.045; 0.060 to 0.011%; 0.022 to 0.007%. No rephosphorization occurs, even though ingot teeming takes 20 min. Similar practice deoxidizes steel with a very acid slag. At the Ugine works this is prepared in an electric furnace over a bath of steel (the latter to conduct current). A practicable composition is 70% SiO_2, 25% Na_2O, 5% CaO. Representative analyses of oxygen in the steel before and after are 0.055% to 0.016%; 0.083 to 0.26%; 0.061 to 0.012%.

FIRST step in the preparation of a chrome ore or magnesia cement for lining an Ajax Wyatt induction furnace is mixing the cement with water. P. S. Kingsley, writing in May *Metals & Alloys*, prefers to mix the cement just before use to avoid evaporation. Tempering over night is not necessary if the water has been added in small amounts and the mixture thoroughly raked. The water should be carefully measured, as even 2% variation is harmful. In ramming too great a force will cause flow of the cement already in place with consequent cracks; the author recommends a riveting hammer. Too much cement should not be rammed at one time because the top layer will be harder and denser. A 3-in. coating with the surface well broken up so the next layer can bind into it will prevent layer cracks. The **RAMMED LINING** is allowed to dry 48 hr. at room temperature and the wooden core of the secondary channel burned out with a resistance strip. The cement is then baked 48 hr. at 200° F. and 48 hr. at 400° F., also preferably with a resistance



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Concentrates

strip. Final heating is done with a gas torch flame turned low and gradually increased. A special water-cooled torch is illustrated.

STUDIES by Wiest on the influence of grain size on lattice parameter, and by Bain on its influence on hardenability, have led Prof. Arthur Phillips and R. M. Brick to the conclusion that **GRAIN SIZE** and grain boundary effects may be of considerable practical importance in alloy equilibrium systems. Their investigations of these effects (reported in *Journal* of the Franklin Institute for May) were made on fine and coarse-grained wire and single crystals of aluminum copper. X-rays determined the relationship between solubility limits and grain size. The solubility line of fine-grained material intersected the eutectic (548° C.) at 5.6% Cu — the generally accepted limit — but single crystals were calculated to hold 7% Cu in solution. At lower temperatures the lines appeared to converge. Conductivity tests at elevated temperatures to determine solubility were in close agreement with the X-ray data.

THE May Lecture of the British Institute of Metals was given by Prof. Albert Portevin on the "Quenching and Tempering of Alloys." He pointed out that recent studies have proven that so many alloys can be improved by heat treatment that the allotropic transformation of iron makes the heat treatment of steel a rare and exceptional case. He also pointed out that whereas it is generally possible to secure physico-chemical equilibrium in an alloy, as defined by the equilibrium diagram, and also a state of elastic equilibrium (where internal stresses approach zero) structural equilibrium, or complete separation and agglomeration of phases, is only an ideal. Since **QUENCHING** puts an alloy in a state of non-equilibrium, any other cause which disturbs equilibrium may be

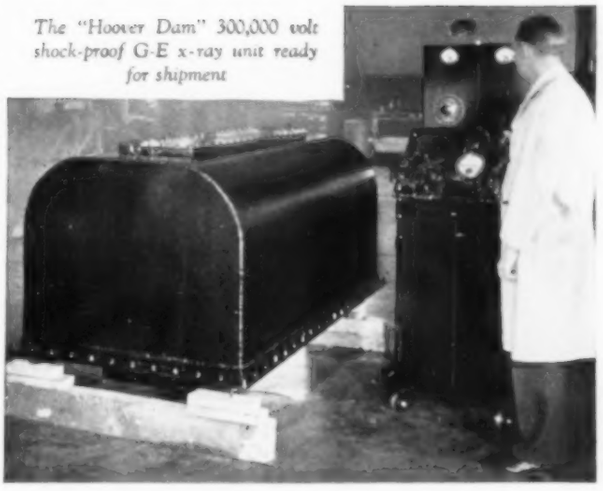
Concentrates

looked upon as giving the same effect as quenching. Or, stated in another way, there may be as many theories of hardening as there are causes which disturb equilibrium; they frequently correspond with the habits of mind and education of the respective theorists. Some require mechanical models; others can explain things by energy and attractions. Unfortunately the practical importance of these ingenious theories has so far been zero.

Since the phenomena of quenching are those of an unstable state, the *dynamics* must be studied — that is, the changes must be measured as they are taking place. Furthermore, simultaneous measurements should be made of as many physical properties as possible, such as dilation, resistivity, heat content, or magnetism. When the laws of quenching are known, definite industrial applications and predictions can be made from them.

A REVIEW of the post-war literature about flakes in gun steel shows that expert opinion, which then held that these small internal fractures in alloy steel are due to oxidized slag inclusions, has veered to the view that while the cracks are at boundaries of primary dendrites where slag inclusions naturally exist, they are really caused by internal stresses. It is thought that volume changes taking place during the transformations Ar_1 and Ar_3 would be sufficient to cause fractures if these transformations occur at different temperatures in closely adjacent portions, as could easily happen if these portions of the highly alloyed outer zones of the dendrites have somewhat different concentrations of the alloying elements. A group of metallurgists at Technische Hochschule, Breslau, have re-examined the evidence on **FLAKES** (abstracted in *Metals & Alloys*, April, 1933) and agree with the last-mentioned view. They suggest that the smooth-surfaced flakes and the coarse granular flakes are essentially the same, but that they have formed at

The "Hoover Dam" 300,000 volt shock-proof G-E x-ray unit ready for shipment



G-E X-Ray Equipment to radiograph penstocks at Hoover Dam

WHEN Babcock & Wilcox were awarded the penstock contract for the colossal Hoover Dam project, they found themselves faced with the mammoth task of checking every inch of all fusion welds by radiographic inspection. *These fusion welds totaled more than 75 miles in length!*

Based on their experience with G-E x-ray equipment in their Barberton plant, Babcock & Wilcox turned to the General Electric X-Ray Corporation for apparatus which would fulfill these stipulations. As a result, they have been equipped with the 300,000 volt oil-immersed x-ray unit shown here.

This equipment, the most powerful shock-proof industrial x-ray apparatus in use at the present time, has its complete high tension system — transformers, condensers, Kenotrons and x-ray tube — completely immersed in oil and sealed within a compact tank or "head." This head will be so mounted that the x-rays can be quickly directed at any angle required. There is no possibility of accidental high tension shock, as the only external wiring is at low tension, connecting the head, control stand, and power source.

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different stages of the processing. The authors exclude "woody fracture" and nodular or conchoidal fractures from the category of flakes. Remedies suggested have to do with the casting of fine-grained ingots, reducing primary segregation by long annealings, heating and cooling very slowly through the transformation.

AGING of sheet steel increases stretcher strains and decreases ductility. Quantitative data were prepared by R. O. Griffis, R. L. Kenyon and R. S. Burns and presented at the May meeting of the American Iron & Steel Institute. Uniform, high quality sheets were used and changes in physical properties indicated by means of stress-strain curves, the variables being amount of cold work, aging temperature, and aging time. Freshly rolled sheets show no sharp yield point, but after **AGING** for 10 min. at 212° F. the curve flattens out at the yield point. Increasing aging time increases the elongation at the yield point, raises the yield point and tensile strength, and decreases total elongation. The higher the aging temperature, the less the time required to show a sharp yield point on a tensile test. Severity of stretcher straining increases with aging time and temperature. The same changes occur at room temperature but require days and weeks instead of minutes. Increasing the amount of cold work in all cases delayed the aging effect and the appearance of stretcher strains but is not of much practical value because of impaired ductility.

SEVERAL essential considerations have been observed by the British Navy in its development of arc **WELDING FOR WARSHIPS** to a point where it is the general policy to use it in lieu of riveting in metal up to $\frac{3}{4}$ in. thick, according to C. S. Lillicrap (*Engineering*, April 11). Among these is that high strength in the weld metal for principal joints is secondary to ductility; the latter *(Cont. on page 58)*

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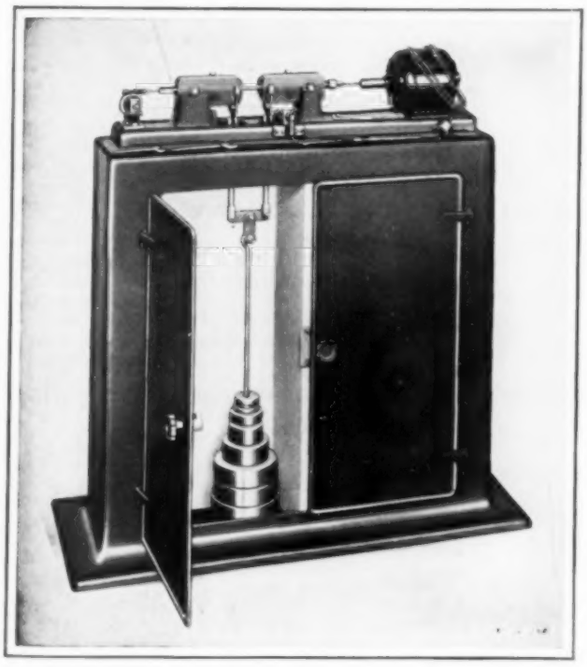

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Art of Metallography

Bausch & Lomb Optical Co. offers a 130-page book, "Optical Instruments for Examining Metals," which is a beautifully executed source of information on this subject. The book is at once a convenient reference text on optics, a treatise on photomicrography and a catalog of B. & L. products. Bulletin Jn-35.

Laboratory Ware

Alundum laboratory ware, made by Norton Co., is strong, has high heat transfer properties and a long life. To clean, simply wash and ignite to constant weight. A booklet describing its applications for filtration, ignition and incineration attractively shows shapes and sizes. Bulletin Jn-88.

Sheffield Steel

Wm. Jessop & Sons, Inc., in a recent publication explain why their Sheffield Superior oil hardening steel does not distort and is easily machined. They assign as reasons a special anneal and a proper balancing of the carbon, manganese and tungsten contents. Full details are presented in Bulletin Jn-61.

Melting Aluminum

Aluminum and white metal alloys are easily and efficiently melted in the new model AT pot furnaces made by American Electric Furnace Co. New design features make for accurate temperature control, freedom from contamination of the melt and easy pouring. A complete description is given in Bulletin Jn-2.

Resistance Wires

Every user of electric furnaces will be interested in a new 40-page booklet prepared by Hoskins Manufacturing Co., to present data on nickel-chromium wire for electrical resistance use. A valuable feature is a new table of temperature emf. values on Chromel-Alumel thermocouples as established by the Bureau of Standards. Bulletin Jn24.

3 Handy Charts

Brown Instrument Co. has printed three handy tables on durable cardboard for use in the heat treating department or laboratory: A conversion table for the Fahrenheit and Centigrade scales, a table of melting points of chemical elements and a heat color chart showing actual colors from 900° to 2200° F. Bulletin Jn-3 .

Furnace Heat Transfer

The practical application of the coefficient of heat transfer from furnaces to material is emphasized in a new folder of Electric Furnace Co. The folder is a reprint of two recently published technical papers which contain much valuable information for operators of electric or fuel fired furnaces. Bulletin Jn-30.

New Type Furnace

A new bell-type retort furnace made by American Gas Furnace Co. can be used in quick succession for carburizing, nitriding, bright annealing in gas atmospheres, or for hardening, normalizing, tempering or annealing. It is an ideal heat treating tool where production is widely varied in character. Bulletin Jn-11.

Heat Resisting Paint

A new booklet put out by E. F. Houghton & Co. describes their acid and heat resisting paint, Houghto-Kote, which can be applied to any surface to resist severe corrosion. It can be brushed, dipped or sprayed on and resists heat up to 600° F. Bulletin Jn-38.

Automatic Polishing

The "Guthrie-Leitz" automatic polishing machine, product of E. Leitz, Inc., by means of a magnetic holding and oscillating device eliminates the human equation from specimen polishing. Pressure, speed, time and amount of abrasive can be controlled so that uniformly polished specimens can be produced even by unskilled operators. Bulletin Jn-47.

Beryllium Copper

A new copper alloy possessing excellent physical properties which may be greatly improved by heat treatment is described in a booklet of American Brass Co. Adding 2.25% beryllium to pure copper produces the remarkable properties described in the booklet. Bulletin Ma-89.

High Cr Cast Iron

A pamphlet describing foundry production of cast irons containing from 15 to 30% of chromium has been issued by Electro Metallurgical Co. These cast irons do not grow or scale after repeated heatings and are excellent for high temperature work. Bulletin Ma-16.

Welding Stainless

An unusual amount of practical data is contained in a fine booklet just put out by Republic Steel Corp. which gives recommendations for welding the several Enduro stainless alloys. Generously illustrated. Bulletin Jn-8.

Nitriding Facts

Information on possible new applications of Nitralloy and the nitriding process in view of recent developments may be obtained from Ludlum Steel Co. New economies in production and a better product may now be obtained. Bulletin Jn-94.

Recuperators

The complete story of recuperators built by Carborundum Co. for industrial furnaces is told in a readable booklet. The range of types available is described and the operating conditions are outlined in a clear manner. Bulletin F-57.

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Furnace Parts

Various parts for furnaces made from alloys manufactured by Driver-Harris Co. are pictured and described in an interesting publication. Complete performance data and specifications of Nichrome and Chromax heat resisting alloys are given in the booklet. Bulletin N-19.

Cyanides and Salts

Metallurgists will find valuable information in an 80-page booklet published by R & H Chemical Department of E. I. du Pont de Nemours Co. Technical information on the heat treatment of steels with cyanides and salts is presented in a lucid manner. Bulletin D-29.

Which Cast Iron?

A novel and very valuable self-reading chart for anyone interested in cast iron has been compiled by International Nickel Co. The device recommends analysis and heat treatment and gives physical properties for cast irons suitable for 50 different applications. Bulletin My-45.

Stainless Sheets

A very useful booklet describing the stainless steel sheets and light plates made by American Sheet & Tin Plate Co. gives recommendations for fabrication and a description of finishes and analyses available. Bulletin Ap-96.

Pickling Inhibitors

A pamphlet describing the nature and use of Grasselli Inhibitors is available to all those interested in the pickling of steel. It not only describes the merits of these inhibitors, but it gives a table of suggested inhibitor strengths to be used in the pickling of the various grades of steel. Bulletin Ap-95.

Closer Heat Control

Anticipatory control action may be obtained with any pyrometer controller by adding the Deoscillator developed by Foxboro Co. A new folder tells how the device prevents over-controlling by augmenting the thermocouple emf. when the temperature is low and opposing it when the temperature is high. Bulletin Ap-21.

"Vee-less" Arc Welds

New literature covering a very recent development in arc welding has been prepared by Metal & Thermit Corp. Known as Murex Straight Gap welding, the new process eliminates grooving or "veeing" the edges even of heavy plates. Welding time is halved and other savings are effected, it is claimed. Bulletin My-64.

Heat Distribution

The advantages gained by uniform temperature distribution throughout furnace charges are fully described in a publication of Westinghouse Electric & Manufacturing Co. In properly designed electric furnaces, heat can be accurately distributed and controlled, with resultant great savings in cost. Bulletin MP-5-33.

To Prevent Rust

The well known rust preventive, No-Ox-Id, is now available from Dearborn Chemical Co. as a foundation for paint. It is available in the colors red, gray or black. A booklet explains how maximum resistance to corrosion can be obtained. Bulletin Ju-36.

Low Cost Recorder

Inexpensive dependability in measuring and recording temperature is the great asset of the new Leeds & Northrup round chart Micromax indicating recorder which brings the reliability and easy maintenance of the motor-driven null recorder to a new low cost. Bulletin Ap-46.

Fatigue Testing

That much discussed topic—fatigue testing—is covered in a publication of Thompson Grinder Co. Interesting data on fatigue of metals and a description of the rotating beam type of fatigue testing machine are presented. Bulletin D-23.

Big-End-Up

Gathmann Engineering Co. briefly explains the advantages of steel cast in big-end-up ingots, showing the freedom from pipe, excessive segregation and axial porosity. An 82% ingot-to-bloom yield of sound steel is the usual practice. Bulletin Fe-13.

Extensometer

A simple but rugged extensometer has been developed by Union Carbide & Carbon Research Laboratories. A booklet describes how it works and how to use it for determining either yield point or as a strain gage to show elongation under specified load. Bulletin Ma-63.

Turbo Compressors

A series of three bulletins is available from Spencer Turbine Co. describing their Turbo Compressors for oil and gas fired equipment and foundry cupolas. Sizes range from 100 to 2,000 cu. ft., 1 to 300 h. p., 8 oz. to 5 lbs. Bulletin Fe-70.

Cast Vanadium Steel

Jerome Strauss and George L. Norris have written a technical booklet for Vanadium Corp. of America describing the properties developed by steel castings containing various percentages of vanadium. The information given is complete and authoritative. Bulletin S-27.

Globar Elements

Globar electrical heating units and a variety of accessories for their operation have been catalogued by Globar Corp. A list of the standard industrial type heating elements and a coordinated list of terminal mountings and accessories is included. Bulletin N-25.

Titanium in Steel

An elaborate catalog prepared for technical readers describes the use of ferro-carbon titanium in steel. Titanium Alloy Manufacturing Co. prepared it. The application of titanium in steels for forgings, castings, rails, sheets and plates is thoroughly described. Bulletin J-90.

Scleroscopes

The model D standard recording scleroscope is described and illustrated in a recent publication of Shore Instrument Co. The theory and practice of hardness testing with this portable machine as described in this bulletin reveal a fund of valuable facts. Bulletin S-33.

X-Rays in Industry

General Electric X-Ray Corp. has available a profusely illustrated brochure entitled "Industrial Application of the X-Ray," which gives the complete story of the field of application of this modern inspection tool. Valuable information is presented. Bulletin Ma-6.

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(Cont. from page 54) is secured by the exclusive use of heavily covered electrodes, kept quite dry in canisters. While internal stresses on the order of 20,000 lb. per sq.in. may be expected when welding parts rigidly fixed in place, these can be neutralized or avoided by careful design of lap (rather than butt) joints and correct welding procedure. Distortion (most evident in thin plating) is minimized by intermittent welding, welding from center toward ends, and using several runs with small gage electrodes. Any riveting (in composite designs) must be done after the welding in the vicinity has been completed.

Welding of mild steel presents no difficulties and can be done as cheaply as riveting. When welding high tensile alloy steels (0.35% carbon is the top limit) great care is taken to minimize the heat effect by welding with minimum current (specified by the supervisor). Galvanized steel can be welded without removal of the coating; the zinc does not harm the joint, but oxide fumes must be carefully ventilated.

AN EXTENSIVE study of steel castings was presented to the May meeting of the British Iron & Steel Institute as the "First Report of the Steel Castings Research Committee." This work was undertaken in 1927 as an investigation of existing castings, and the first part of the report discusses various defects such as blowholes, shrinkage cavities, and cracks, with particular reference to some columns and hydraulic cylinders. In 1928 the work was more fully organized and a design for a steam header was submitted to a number of foundries. Sixteen experimental **STEEL CASTINGS** were then made according to proposals received from the foundries as to the position of the runner and of the casting in the mold, effect of variations in the weight, area, and spacing of the heads and flanges, rate of filling the mold, and casting temperature. These castings were tested and the report summarizes the findings.

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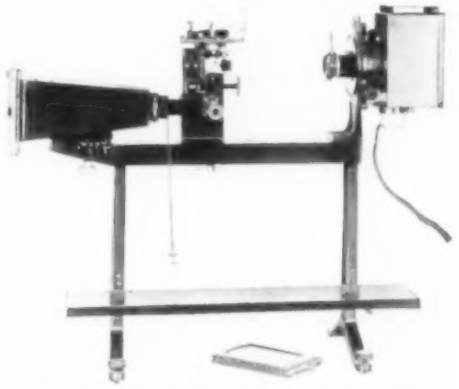

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Brake drums fail in bus service on mountain roads where braking is long and severe through wear and heat checking. The effect of exessive heat is especially damaging. Microscopic studies seem to show a change in structure; that is, sections through a "sound area," and another section near a cracked area, show an increase in size of the graphite flakes.

In some designs the drums are of cast iron and are attached to the wheel. In another type, known as "centrifuse," the cast iron is fused to a steel backing ring, which acts as a mold for a centrifugal casting.

General Remarks

Metallurgical control is more important in high strength and special cast irons than in ordinary cast irons. Anybody with a cupola can make some kind of iron, but high strength irons require close metallurgical control and supervision to produce uniform and good results.

High strength iron is no cure-all. Just as in the steel industry where the big tonnage is still low carbon steels, so in the cast iron industry the big bulk of castings will be non-alloy castings of the low and medium strength variety. There is no advantage in producing a strong iron where a weaker and more machinable iron will serve the purpose satisfactorily.

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As the scaling in an actual heating operation will not be limited to the time at temperature, but is also occurring during the heating up period, the total amount of scale formed will be considerably in excess of the amount determined for one hour at 1700° F., and will vary with the rate of heating during the first period. However, for purposes of comparison it may be assumed that the combined effect results in doubling the amount of scale. The loss in thickness of metal for the oxidizing atmosphere then becomes 0.008 in. as opposed to 0.002 in. for the reducing atmosphere — a very appreciable difference.

The heating of a cold forming die block 12x12x6 in. (0.90 to 1.05% carbon steel) in an atmosphere carrying 1 to 1½% oxygen at a temperature of 1650 to 1700° F. for one hour will result in a metal-loss of from 0.36 to 0.41 lb. depending upon the carbon content. This will correspond to a metal thickness loss of 0.002 to 0.0025 in. The use of an atmosphere approaching closely to that obtained with neither excess fuel nor air (or if the dangers of decarburization could be avoided, one containing 1% of carbon monoxide) would result in saving 60% or more of this loss.

With an increase of the dimensions of the part being treated, the time of heating up is necessarily extended and the scale formed during this period becomes a more important part of the total. The relative effect, though, of the change from oxidizing to reducing atmosphere will be indicated by the values given on the curves.

The effects to be obtained with the change in character of the furnace atmosphere on the alloy steels appear to follow fairly closely those obtained with the low or the high carbon steel. If a part made of an S.A.E. 6145 steel is heated one hour at 1700° F. in a neutral atmosphere the thickness of metal lost would approximate that shown by the high carbon steel under similar conditions. Use of a reducing atmosphere carrying 2% CO would cut this loss 60% or more.

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